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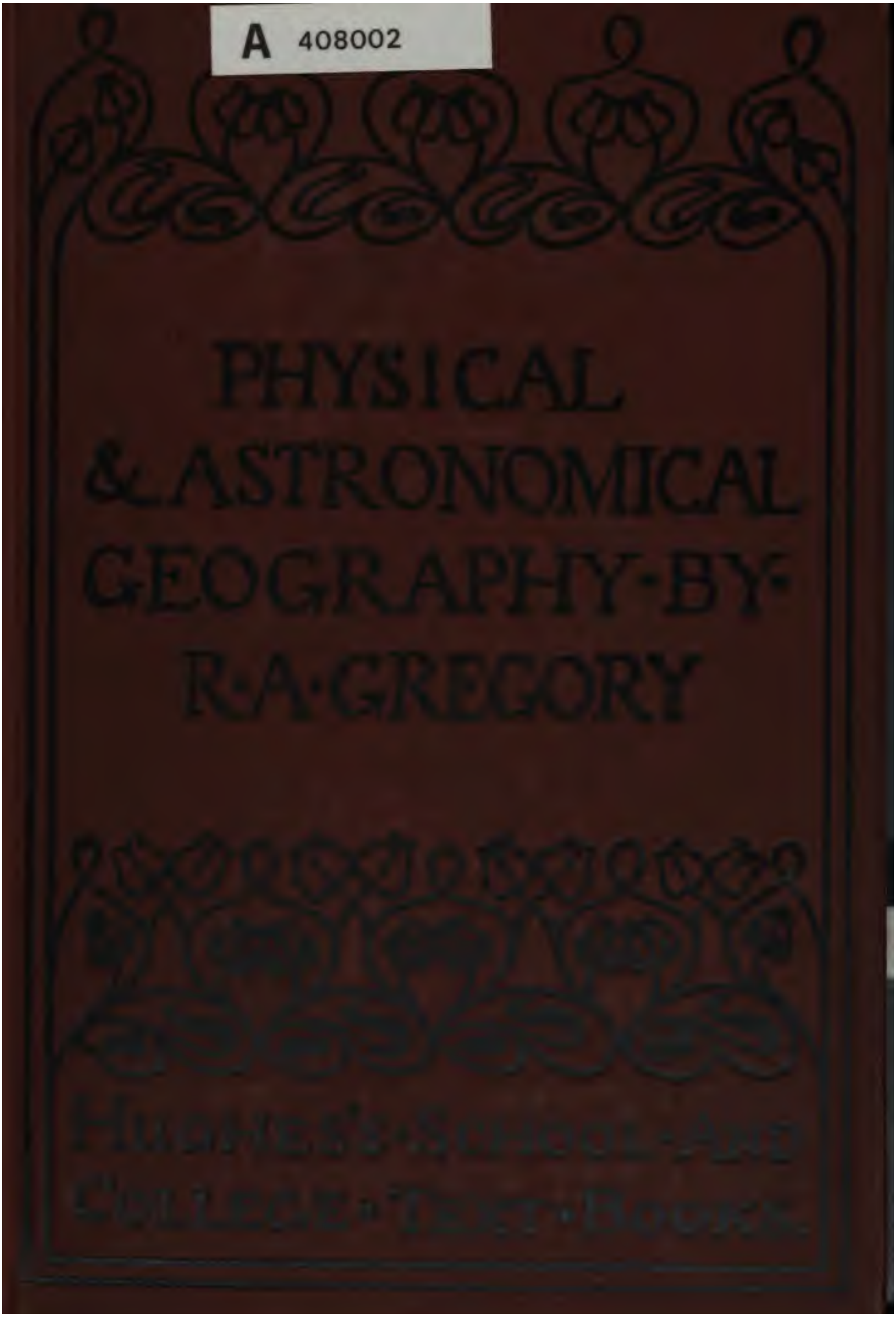

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ELEMENTARY
PHYSICAL & ASTRONOMICAL
GEOGRAPHY.

ELEMENTARY
PHYSICAL AND ASTRONOMICAL
GEOGRAPHY.

SPECIALLY DESIGNED FOR PUPIL TEACHERS,
STUDENTS IN TRAINING, AND SCIENCE STUDENTS.

BY
R. A. GREGORY,
Oxford University Extension Lecturer; Honours Medallist in Physiography; Author of Elementary, Advanced, and Honours Physiography; formerly Computer to Solar Physics Committee, the Royal College of Science, South Kensington; Fellow of the Royal Astronomical Society; Foreign Correspondent to the Revue Générale des Sciences.

With Original Illustrations.

FOURTH EDITION.

LONDON:
JOSEPH HUGHES & CO.,
PILGRIM STREET, LUDGATE HILL, E.C
1893.

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PREFACE.

PHYSICAL GEOGRAPHY may be defined as the science which deals with the earth as a member of the solar system, the properties and motions of bodies upon it, the causes that affect the natural features of land and water, and the distribution of life over its surface.

This work has been designed to cover the whole of the physical geography required by pupil teachers, and for the scholarship and certificate examinations.

No attempt has been made, however, to limit the information by a too strict adherence to the prescribed syllabus, for it is hoped that the book will serve as an easy introduction to a most interesting science as well as a guide to study. At the end of each chapter a general summary is given of the matter it contains; this summary will not only serve to call to the student's mind that which he reads in a more extended manner in the various chapters, but is intended to be a sort of guide as to the manner in which examination questions should be answered.

Although the Physiography syllabus of the Science and Art Department has a somewhat different range from that for which this work is intended, there is no doubt that the student who reads and understands the subject as it is here treated is sure to obtain an elementary, if not an advanced, certificate at the May examinations.

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PREFACE.

In the new Science and Art Directory the examiners in physiography note that candidates for examination will be required to answer questions relating not only to physical geography, but also to the astronomical portion of the subject. This part has been fully treated in the following pages.

I have had to refer to various works for many of the facts contained in the following pages. Chief among these are Haughton's 'Lectures on Physical Geography,' and the 'Challenger Reports.' My deepest obligations, however, are due to my friends, Mr. W. Scudamore, Associate of the Normal School of Science, and Mr. George Stephenson, Science Master at 'The Schools,' Cheadle Hulme. I am indebted to the former gentleman for many of the illustrations, and to both for careful revision of the proof sheets.

RICHARD A. GREGORY.

SOLAR PHYSICS LABORATORY,
ROYAL COLLEGE OF SCIENCE, SOUTH KENSINGTON.

PREFACE TO THE SECOND EDITION.

A SECOND EDITION of this work being called for, I have taken the opportunity of making a few alterations and additions kindly suggested to me by teachers. A table showing the proportion of the most abundant elements in the earth's crust has been introduced on p. 169, and it has been thought advisable to give, in an appendix, a list of rainless regions, with the reasons for the aridity of each, and a brief account of the order of superposition of stratified rocks.

R. A. GREGORY

November, 1891.

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CHAPTER I.

LINEAR AND ANGULAR MEASUREMENT.

In order to facilitate the study of the astronomical portion of Physical Geography and to prevent the breaking up of the matter contained in the various chapters, the general principles required are given here collectively. They mainly consist of simple rules used in mensuration and of a few geometrical definitions.

Every one knows that a plane surface means an even or level surface—for example, the top of a billiard table or the side of a house; and it is easy to understand that a straight edge would lie upon such a surface in any direction. If, however, the surface be curved in the faintest, there are directions in which the straight line will not touch it all along.

Consider two observers to be looking at a particular star, and let imaginary lines join the eye of each observer to it and to each other; by this means an enormous triangle would be formed. Conceive now a sheet of something to pass through these three points and to extend in all directions; such a sheet would be the plane of the triangle and the only plane that could be described as long as the observers and the star remained in their same positions. Hence, any plane is completely determined when we know three points through which it must pass. In Astronomy such imaginary planes are constantly used for reference, and objects are said to be so much above or below them according to their position.

Euclid's definition that '**A circle** is a plane figure contained by one line, which is called the circumference, and is such that all straight lines drawn from a certain point within the figure to the circumference are equal to one another,' is generally understood, although we may not express our idea of a circle in precisely the same language. It need only be added that any straight line drawn from the centre to the circumference is called a radius of the circle, and that a straight line drawn through the centre and terminated both ways by the circumference is called a diameter. The diameter of a circle, therefore, is twice the radius.

If the circumference of any circle be exactly measured, and the diameter also, it will be found that the former is 3·14159 times longer than the latter; hence, if the diameter of a circle be known, its circumference may be found by multiplying it by 3·14159, or, conversely, if the circumference of a circle be known, the diameter may be found by dividing it by 3·14159. This relation between the diameter and circumference of a circle does not terminate in the fifth decimal place as our figures would indicate, but has been carried as far as the seven hundredth decimal figure without terminating. For most practical purposes, however, the relation may be taken as 3·1416 or, expressed in vulgar fractions, $3\frac{1}{7}$, that is $\frac{22}{7}$.

For example, the radius of a circle is 10 yards; find its circumference.

The diameter of the circle $= 10 \times 2 = 20$ yards.

Therefore circumference $= 20 \times \frac{22}{7} = \frac{440}{7} = 62\frac{6}{7}$ yards.

It is often required to find the area of a circle, having given the diameter, the radius or the circumference. If the length of the circumference be given we divide it by $\frac{22}{7}$ to find the diameter and having done this we divide the result by 2 to find the length of the radius. Then to find the area of the circle the square of the radius must be multiplied by $\frac{22}{7}$. For example, the radius of a circle is 5 feet; find the area of the circle. The square of any number is that number multiplied by itself, hence the area required is $5 \times 5 \times \frac{22}{7} = \frac{550}{7} = 78\frac{4}{7}$. Thus the area of the circle is $78\frac{4}{7}$ square feet.

A **sphere** may be defined as 'A solid bounded by a surface, every point of which is at the same distance from a fixed point in the interior called the *centre*.' Any sphere may be cut in two ways. If the cut be made through the centre the sphere is divided into equal parts, and the circular outline bounding each of the halves is called a *great circle*. All other sections of a sphere are circular in outline, but smaller in area than a great circle, so they are called *small circles*.

Now it can be shown that the superficial area of a hemispherical dome is twice the area of the great circle on which it rests, hence the area of a sphere, which may be looked upon as two domes stuck together, is four times the area of the central section, so that if we cut an orange in half and find that the area of the circular portion is 8 square inches, then the area of the whole orange peel is 4 times 8 = 32 square inches.

Place an orange or some other spherical body in a cylindrical vessel into which it exactly fits, the top of the sphere being level with the top of the vessel; then pour in water to the brim and afterwards remove the sphere. It will be found that the height of the water is only $\frac{1}{3}$ the height of the vessel, that is to say, the sphere must have taken up $\frac{2}{3}$ of the volume of the vessel, or, expressed in more geometrical language, we say that the volume of a sphere is $\frac{2}{3}$ the volume of the circumscribing cylinder. Now, the volume of any cylinder is the area of its base multiplied by its height. But the diameter and the height of the circumscribing cylinder are each the same as the diameter of the sphere, and therefore each equal to twice the radius of the sphere. Hence, to find the volume of the cylinder into which a sphere 3 inches in radius exactly fits, we proceed as follows:—

$$\begin{aligned} \text{Area of base} &= (\text{radius})^2 \times \tfrac{22}{7} \\ &= 3 \times 3 \times \tfrac{22}{7} \\ &= \tfrac{198}{7} = 28\tfrac{2}{7} \text{ square inches.} \end{aligned}$$

$$\begin{aligned} \text{And volume of cylinder} &= \text{area of base} \times \text{height} \\ &= 28\tfrac{2}{7} \times \text{twice the radius of sphere} \\ &= 28\tfrac{2}{7} \times 6 \\ &= 169\tfrac{5}{7} \text{ cubic inches.} \end{aligned}$$

And the volume of the sphere $= \frac{2}{3}$ of $169\frac{5}{7} = 113\frac{1}{7}$ cubic in.

Another geometrical figure with which we shall have much to do is called an **ellipse.** To construct such a figure, fix two pins in a drawing board and tie a loop of thread somewhat longer than the distance between them; place the loop on the pins and stretch it by means of a pencil. By keeping the pencil in the loop and moving it round, an outline may be drawn similar to that shown in Fig. 1. It is evident from the method of construction that the distance from one of the pins to the other pin around the pencil is always the same—in fact, the definition of an ellipse is that it is 'a plane figure such that the sum of the two distances from any point on its circumference to two points, called the foci, within is always the same.' Hence the point occupied by each of the pins used in the construction is a focus of the ellipse formed. The longest and the shortest distances across an ellipse are called respectively the

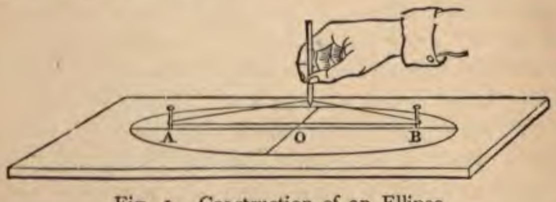


Fig. 1. Construction of an Ellipse.

major and the minor axes. The two axes are therefore always at right angles to one another, and the point where they cut is called the centre of the ellipse. The eccentricity of any ellipse is the distance from the centre of the ellipse to either of the foci divided by the length of the semi-major axis. Thus if the greatest distance from the centre to the circumference of an ellipse were 3 inches, and that from the centre to the focus 2 inches, the eccentricity would be $\frac{2}{3}$, or, conversely, if the eccentricity of an ellipse be said to be ·25, this means that the distance between the centre and the focus is ·25 or $\frac{1}{4}$ the length of the semi-major axis.

The smaller the eccentricity of an ellipse the more the ellipse approaches the form of a circle—in fact, a circle may be looked upon as an ellipse in which the centre and the foci coincide, that is, an ellipse of no eccentricity. If the major axis of an ellipse be made infinitely long, a figure called a **parabola** is formed, which is not a closed curve like an ellipse or a circle. Starting from one extremity of the major axis of an ellipse we see that the distance between two opposite points on the circumference gets greater and greater until the minor axis is reached; then the curve approaches the major axis until the other extremity is reached. In a parabola, however, the more the opposite sides are prolonged the greater will be the

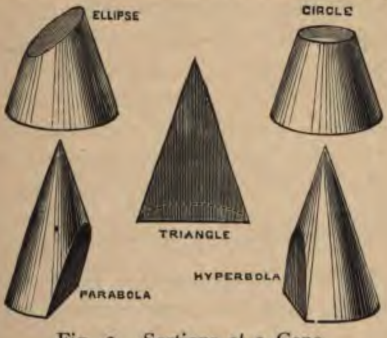


Fig. 2. Sections of a Cone.

distance between the two branches, hence they never meet. It is evident, therefore, that a body moving in an elliptical path goes round and round the foci until its motion is ended; a body having parabolic motion, however, only traverses the same path once, and leaves the focus never to return again.

These geometrical figures may also be deduced from sections of a cone which every scholar sees in a school. A circle is thus a section cut parallel to the base of a cone, an ellipse is that section of a cone formed by a plane passing obliquely through opposite sides, and a parabola that formed by a plane parallel to one of the sides (Fig. 2).

Force is that which tends to alter a body's state of rest or of uniform motion in a straight line. If we see anything in motion we know some force must have started it, for it could not move of itself. The consequence is that a body moves in the direction of the force that has set, or is setting, it in motion. When two forces act upon a body at the same time it does not move in the direction of either of them, but in a direction which is a sort of mean between the two. Thus if AB and AD in Fig. 3 represent, both in magnitude and direction, two forces acting on a particle at A, motion will take place in the direction AC, which, it will be seen, is the diagonal of the parallelogram ABCD. AC is called the *resultant force* of the two *components* AB and AD. As an example of this motion consider two horses towing a barge; the barge does not move in the direction of either of the tow ropes but up

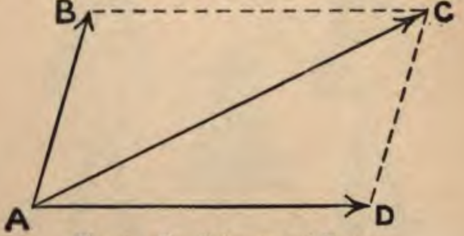


Fig. 3. Parallelogram of Forces.

the river. Again, if a ball be thrown straight out from the top of a cliff we know that it always reaches the bottom, because of the attraction of the earth. If the earth did not attract the ball it would move on for ever in the direction in which it was thrown, but because of this second force it moves in a curve, which is really a parabolic one, and finally reaches the surface (Fig. 4).

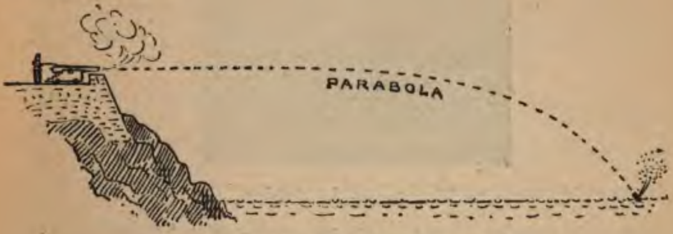


Fig. 4. Parabolic Path of a Projectile.

In order to measure linear distances some line must be fixed upon as the standard. In England the unit of length is a foot, in France it is a metre, which is equal to about $3\frac{3}{11}$ English feet. We cannot, however, speak of angles as being so many feet or inches long or wide, but must use some angle as the unit, and refer all others to it; so that the measure of any angle is the number of times it contains the unit angle. Now, all units should be invariable, that is, constant in size. A right angle is invariable. The definition given by Euclid is, 'When a straight line standing on another straight line makes the adjacent angles equal to one another, each of the angles is called a right angle.' The straight line which stands on the other is called a perpendicular to it (Fig. 5). Thus the unit of angular measurement could be a right angle, but it possesses the disadvantage of being inconveniently large, so it is divided into 90 equal parts, each of which is called a degree; these again are divided into 60 equal parts called minutes, and the minutes are also divided into 60 equal parts called seconds.

A right angle therefore contains 90 degrees, or 5,400 minutes, or 324,000 seconds. It is convenient not to have to write the words degree, minute and second, so the symbols °, ′, and ″ are used to express them—thus twenty degrees, thirty minutes, six seconds is written 20° 30′ 6″.

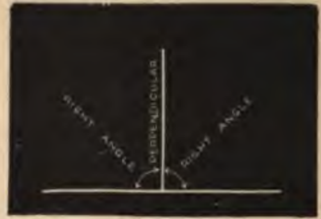


Fig. 5. Right Angles.

Let two diameters of a circle be drawn at right angles to one another, then it will be seen that four right angles are encircled by the circumference, and that if each of them be divided into 90 equal parts the whole circumference will be divided into 360 equal parts. The size of the circle is immaterial; if it be divided into 360 equal parts, each of the parts will represent one degree. Take a pair of compasses the legs of which are close together—there is, therefore, no angle contained between them; when opened to the fullest extent the angle is 180°, and when one leg is perpendicular to the other the included angle is 90°. Now, if we took a pair of compasses and, looking along the legs from the centre, could so delicately open them that one leg pointed to one edge of the moon, and the other leg to the opposite edge, we should find that the angle between the legs would be about half a degree; and if it were possible to make a similar experiment with the sun we should find the angle would be 32 minutes, that is, a little more than half a degree. Hence in angular measurement the diameter of the sun and moon is about the same, although we shall see later on that the former is incomparably larger than the latter. A pair of compasses would not permit these small angles to be measured, but with delicate instruments, specially constructed for such observations, the determination becomes comparatively easy.

If we observed a particular brick in some wall and wished to point out in writing which brick it was, we have learnt from common experience that it is necessary to say not only what is the height of the brick in the wall, but what its distance from some known point in a horizontal direction is (Fig. 6).

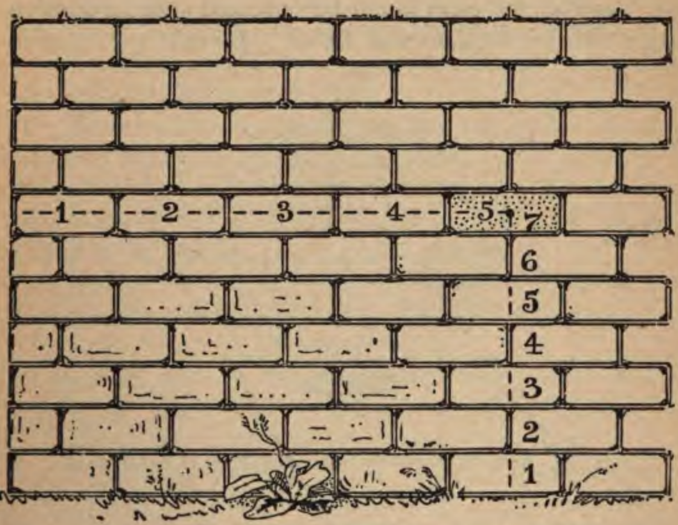


Fig. 6. Co-ordinates of a Point.

Any point in the wall is at once identified if its vertical and horizontal distance be known, and the two distances are called the co-ordinates of that particular point. The position of a point on the earth is determined by co-ordinates called **latitude** and **longitude.** These words signify *breadth* and *length*, and were used by the ancients because of a mistaken notion that the earth's surface was flat and longer from east to west than from north to south.

It is generally known that the earth is spherical in form, and the next chapter contains an explanation of the methods used for determining its exact size and shape. If two lines are supposed to be drawn around the earth, one in a north and south direction called a meridian, and the other from east to west along the middle called the equator, the position of any place on the earth would be indicated when its distance from each of the lines was known. In order to facilitate reference other lines are supposed to be drawn in the same direction as the primary ones, those from east to west being termed **parallels of latitude,** whilst those drawn in a north and south direction are termed **meridians of longitude** (Fig. 7). Each of these distances is measured in degrees, minutes, and seconds, as indicated in the accompanying figure.

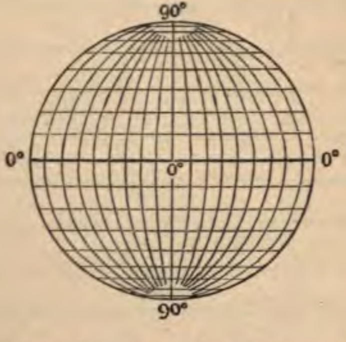


Fig. 7. Parallels of Latitude and Meridians of Longitude.

GENERAL SUMMARY OF CHAPTER I.

A Plane is a Surface such that if any two points be taken in it the straight line joining them lies entirely in that surface.

The circumference of a circle contains the diameter of the circle 3·14159 . . . . times. Instead of writing all these figures the Greek letter π is generally used.

The Area of a Circle is the square of the radius of the circle multiplied by 3·14159. Or, if r denote the radius, then the area $= \pi \times r^2$.

A Great Circle is the boundary line of that section of a sphere which divides it into two equal parts. All other circles on a sphere are called **small circles.**

The Area of the surface of a Sphere is four times the area of a plane passing through the centre, that is, it equals $4 \times \pi \times r^2$.

The volume of a Cylinder is the area of its base multiplied by its height.

The volume of a Sphere is $\frac{2}{3}$ the volume of its circumscribing cylinder, that is, $(\frac{2}{3} \text{ of } \pi \times r^2) \times 2r$, which equals $\frac{4}{3} \times \pi \times r^3$.

An Ellipse is a plane figure such that the sum of the distances from any point on the circumference to two points within, called the foci of the ellipse, is always the same.

The Eccentricity of an Ellipse is the distance between the centre and the focus expressed in terms of the semi-major axis.

A Parabola is a plane figure in which the two foci are infinitely distant from one another.

When any Number of Forces act on a body all their actions are superadded to each other, and the force which acting singly would have had the same effect is termed the *resultant.*

A Degree in angular measurement is $\frac{1}{90}$ of a right angle, and since all the angles made by any number of straight lines meeting at one point are together equal to four right angles, the circumference of all circles may be considered to contain 360 degrees.

The Position of any Point in a plane is known when its co-ordinates, that is, its distance from two other points in that plane, have been determined.

CHAPTER II.

SHAPE AND SIZE OF THE EARTH.

THE first opinion held by primitive mankind with respect to the form of the surface of the earth was that it was flat. More critical glances at natural phenomena, however, must soon have demonstrated that such was not the case, and that the form of the earth is globular; and although we are ignorant of the name of him who first asserted this fact, yet we know that it was taught by Thales six hundred years before the commencement of our era, and plainly enunciated by Plato and Aristotle, whilst Ptolemy, who flourished at Alexandria about A.D. 130, supported the doctrine by arguments employed at the present time.

That the earth is not flat may be gathered from observations of vessels approaching to, and receding from, any sea shore. To an observer on the margin of the sea, a ship approaching the shore appears to rise out of the water. In the distance only the topmasts are seen, then the rigging becomes visible, and lastly the hull. If the ship is moving away from the shore, first the hull disappears, and the vessel is said to be 'hull down,' then the rigging sinks out of sight, and finally, by means of a telescope, the highest parts of the masts can be observed slowly to sink beneath the horizon. Such appearances as these could evidently not happen if the surface of the earth were flat and the disappearances were due to an increase of distance, for then the thin masts would be the first to fade out of sight and the thick hull would remain visible for the longest time. It is evident, however, that these phenomena would occur precisely as described if the surface of the earth be curved (Fig. 8). Similarly when a ship approaches the shore an observer on it first sees the mountain-tops, then the hills, and, finally, the low ground appears.

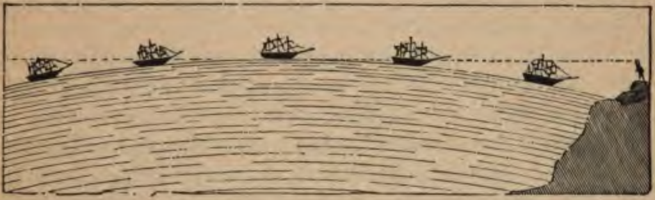


Fig. 8. Apparent sinking of a ship below the horizon caused by the curvature of the earth's surface.

A commonly stated proof that the earth is not flat is said to be afforded by the fact that it has been circumnavigated. But it has been pointed out, by latter-day believers in a flat earth, that this is no proof at all; for if we dwelt on the flat top of a cheese-shaped earth, with the North Pole at the centre of the disc, and the equator midway between the pole and the southern circumference, circumnavigation might be performed as at present. In this case all lines drawn from the centre to the circumference would have a true north and south direction, for the South Pole would be represented by the circumference; and by travelling due east or west it would be possible to return to the starting point on the flat surface without retracing an inch of the way.

But none of the above described phenomena prove the earth to be globular in form. Ships would disappear by sinking beneath the horizon if the earth were egg-shaped; and circum navigation in an easterly or westerly direction only proves that the earth is curved from east to west and would be possible if it were cylindrical like a cheese.

The following are observations which prove that the shape of the earth is spherical like a ball.

If a person stands on a vast plain, or on the deck of a ship at sea, the plain or the sea is seen to extend until earth and sky appear to meet in a line; this line limits the vision in every direction and is called his **horizon.** Now it is found that whether observations be made from the deck or the mast head of a ship, or from the greatest height ever attained by balloonists, the plain stretched out beneath appears bounded by a circular outline, with only this difference, that the greater the height above the surface the larger the circle appears. An ordinary observer whose eyes are six feet above sea level has his horizon three miles off, at ten and a half feet this is extended to four miles, and from the top of a lighthouse ninety-six feet high the horizon line is twelve miles off. But the line is always a circle, and this is a proof positive that the earth is globular in shape, for a globe is the only body which viewed from any point outside gives a circular outline (Fig. 9).

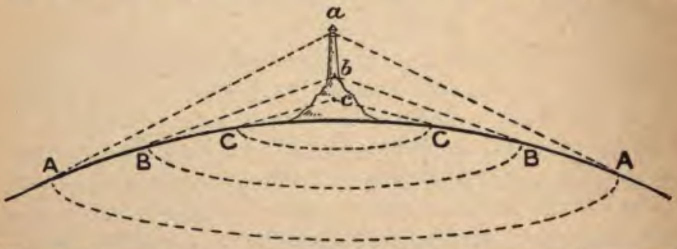
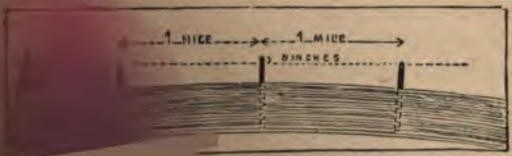


Fig. 9. Increase of the distance of the visible horizon with increase of height above sea-level.

As an illustration of this fact, the case of a fly, or any small insect, on or above the surface of an orange might be mentioned. The fly's vision will always be bounded by a circle of which it is the centre.

For the reason that a circle can only have one centre, every person must have his own horizon—that is, must be the centre of a circular area extending round him on all sides, which area he, so to speak, carries with him wherever he goes In general, however, an observer is not so situated as to be able to see the horizon in every direction.

It might be argued, that since all the other heavenly bodies appear globular, then from analogy our earth is similar in shape; but the most convincing proof known to the ancients is found in the following. At certain intervals of time, when the moon is full a shadow having a circular outline is seen to creep across its face. The moon is then said to be eclipsed, and the shadow through which it passes is that of our earth. Now whenever these eclipses occur, the earth's shadow always appears circular, which demonstrates conclusively that the earth is a globe, for this is the only shape which will always throw such a shadow.



t to prove the earth's curvature.

that if three poles are fixed in line
xactly the same heig

parts of the earth and it was found that the curvature was everywhere the same, this would prove that the earth's form is globular, and an approximate determination of its size could be obtained. It is found that the middle pole rises eight inches above the line joining the two outer ones when the distance between each pole is a mile; and it can be easily proved that in order to describe a circle having a curvature of eight inches in a mile the two legs of a pair of compasses would require to be separated by 3,960 miles. This, then, is the length of the radius of the earth, and the diameter is therefore, approximately, 7,920 miles.

We have seen from the foregoing that the general form of the earth is globular. It is not, however, a perfect globe, but resembles an orange inasmuch as it is somewhat flattened at the top and bottom, and hence there is one diameter which is shorter than any other. The imaginary line passing through the earth's centre and piercing the flattened regions—that is, the earth's shortest diameter—is called the **Axis,** and the extremities of the line are called respectively the **North and South Geographical Poles.**

It is now necessary to give a few definitions and general considerations relating to the determination of the true size and shape of the earth. Imagine the earth floating in space, and ourselves viewing it a few million miles away. Let the axis be produced until it meets the heavens. The points where this axis, produced both ways, appears to cut the heavens are called the **North and South Celestial Poles.** Near the point where the northern extremity of the axis meets the sky, there happens at the present time to be a bright star, which is therefore known as the Pole Star; that is to say, an observer at the north pole would see the pole star right overhead. No bright star, however, marks the position of the south celestial pole.

Besides the geographical and celestial poles, there are the geographical and celestial equators. The **earth's equator** is an imaginary line running around the earth, midway between the north and south poles; hence any place which is at the same distance from the north pole as it is from the south pole is on the equator.

Similarly, the **Celestial Equator** is the great circle equidistant from the north and south celestial poles, and hence a star exactly overhead to an observer on the earth's equator is on the celestial equator. Our globe and the heavens are thus divided into two portions by the equator, one portion containing the north pole and the other portion containing the south pole. These two halves of a globe are therefore respectively called the northern and the southern hemisphere. Circles are conceived to be drawn around the earth parallel to the equator, and since the distance from the equator to either pole is a quarter of a circle or 90°, ninety of these parallels may be supposed to be drawn upon the northern and ninety upon the southern hemisphere. Such circular lines are called **Parallels of Latitude,** and are counted northward or southward from the equator to the poles; thus, a place on the equator is in latitude 0°, abbreviated, lat. 0°, London is in 51½° northern latitude, or lat. 51½° N., and the latitudes of the poles are respectively 90° North and 90° South. We thus speak of places as being in **high latitudes** when they are situated near either pole, and in **low latitudes** when they are near the equator. Intervening places are said to be in **middle latitudes.**

In precisely the same way, the heavens are conceived to be traversed by lines drawn parallel to the celestial equator. But they are called **Parallels of Declination.** All stars exactly over the earth's equator, that is, on the celestial equator, are in Declination 0°, all stars south of the celestial equator are in south declination, and stars north of it have north declination. The declination of the Pole star at the present time is about 88¾° North, or 1¼° from the north celestial pole.

C

We have seen that the visible horizon only extends a few miles from an observer on the earth's surface. Now consider what an observer at the north pole sees of the heavens: the pole star will be nearly vertically overhead, that is, almost in the zenith, and but for the fact that the faint light of stars is blotted out by our atmosphere he would see all the stars in the northern hemisphere. Roughly speaking, half the stars in the heavens could be seen at one time, and those on the celestial equator would just be visible where earth and sky appear to meet. It would appear at first sight that since an observer at either pole can see half the celestial sphere he ought to be able to see half the surface of the earth. We know, however, that this is not the case; and the reason why so much of the celestial sphere is seen is because the earth is but a point when compared with the immensity of space. If observations be made at the equator the pole star appears on the horizon,

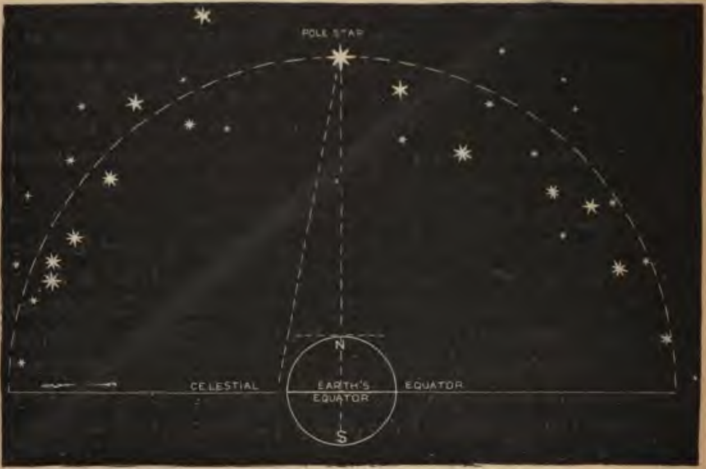


Fig. 11. Increase of the altitude of the Pole Star with increase of distance from the equator.

as is made manifest in Fig. 11. That is to say, an observer in latitude 0° sees the pole star on his horizon, and since the **Altitude** of a body means its height above the horizon a point on the horizon has an altitude of 0°. Let the observer travel in a direct line towards the north pole; the pole star would appear to rise above the horizon until, when the north geographical pole was reached, it would appear overhead—that is, to an observer in latitude 90° the pole star has an altitude of nearly 90°, hence in moving from latitude 0° to latitude 90° the pole star also moves from an altitude 0° to an altitude of nearly 90°, half way between the equator and the north pole, that is, in latitude 45°, the pole star would appear to have an altitude of 45°, and so on for any other point. Thus we arrive at the important law that the altitude of the pole seen from any place on the earth's surface is equal to the latitude of that place. It is by the use of this law that travellers on sea or land can determine the latitude they are in simply by an observation of the pole star. Since, however, this star is not visible south of the equator, nor in the day-time, it is more convenient to use the sun for the purpose of determining latitude.

It now remains to show how by the application of the foregoing principles the exact size and shape of the earth have been determined. Let an observer at the equator, after noting the pole star on the horizon, travel in a direct north and south line until it has risen 1° above the horizon, that is until the altitude of the star is 1°, and let the distance necessary to make this difference of 1° in altitude be measured. Similarly, the distance necessary to travel in order to produce a difference of 1° in the altitude of the pole might be measured at any point. Now it is found that anywhere on the earth's surface the distance necessary to travel in a direct north and south line, to produce a difference of 1° in the altitude of the pole is nearly the same and therefore the earth must be nearly spherical in a north and south direction. If it were cylindrical in shape then the lines drawn from any point on the curved surface to a star would all be parallel, and hence there could be no alteration in the altitude of a star as an observer travelled up and down the cylinder.

From accurate measurements made in different parts of the earth, and from observations of the change in altitude of the celestial pole, it has been found that the average distance required to travel is about 69 miles; this then is the average length of a degree on the earth's surface, and since there are 360° in every circle, the circumference of the earth in a north and south direction is 69 × 360, or 24,840 miles, and its diameter is therefore about 7,904 miles.

These estimations of the lengths of degrees of latitude are called measurements of **arcs of meridian,** because they are made in a true north and south line, or in the meridian. Accurate determinations have shown that the length of **a degree of latitude** is greatest at the poles, and diminishes as the equator is approached.

The following table gives the calculated length of a degree in different latitudes.

Latitude.	Length of one degree.
0°	68·69 miles
10	68·70 „
20	68·77 „
30	68·88 „
40	69·00 „
45	69·05 „
50	69·10 miles
60	69·21 „
70	69·32 „
80	69·38 „
90	69·39 „

The reason for this slight variation is that the earth is not a true sphere, but is flattened at the poles and bulged out at the equator, being very similar in shape to an orange, or an oblate spheroid. This being so, the polar diameter of the earth, or the line joining the north and south poles, must be shorter than a line joining a point on the equator through the earth's centre to a point opposite. The two diameters have the lengths, 7,926 and 7,900 miles respectively, and therefore differ by 26 miles.

To an observer on a flat earth the altitudes of stars would be unalterable. With a very slight curvature it would be possible, by travelling a considerable distance, to change a star's altitude by, say, one degree; and were the curvature still greater the distance necessary to travel to produce the same change would be decreased. In fact, the greater the curvature the less is the length of a degree of latitude; or conversely, since degrees of latitude are longer at the poles than at the equator, the curvature must be less at the poles, that is, the earth is flatter there than in lower latitudes.

GENERAL SUMMARY OF CHAPTER II.

That the earth is not flat is proved by the following :—

(1.) The highest points of approaching objects are the first to become visible, and, in the case of receding objects, the last to sink beneath the horizon.

(2.) If three poles of exactly the same height be placed in a line, the middle one always appears higher than the two outer ones.

(3.) The altitude of stars alters in travelling in a north and south direction.

That the earth is globular in form is proved by the following :—

(1.) The area embraced by the horizon is always circular.

(2.) The shadow of the earth, as seen upon the moon during a lunar eclipse, is always circular.

The **North and South Geographical Poles** are the extremities of the earth's shortest diameter or axis.

The **Celestial Poles** are the points where the earth's axis produced intersects the celestial sphere.

The **Celestial** and the **Geographical Equators** are great circles half way between the two poles, and therefore 90° from each.

The **Latitude** of any place is its distance from the geographical equator in degrees, and is equal to the altitude of the pole at that place.

The **Declination** of a heavenly body is its angular distance from the celestial equator.

The **Length of a Degree of Latitude** is the distance which it is necessary to travel in a north and south line, in order to produce a difference of 1° in the altitude of the pole.

To **Measure a Degree of Latitude** it is necessary:—

(1.) To ascertain very accurately the distance between two points on the same meridian.

(2.) To determine the number of degrees, minutes, and seconds between the two stations by measuring their latitudes and subtracting one from the other. Then, length of Degree of Latitude = distance between the two stations divided by difference of latitude.

That the **Earth is an oblate spheroid** and not a perfect sphere, is proved by the fact that degrees of latitude increase gradually in length from the pole to the equator.

CHAPTER III.

ROTATION OF THE EARTH AND CONSEQUENT PHENOMENA.

Every morning the sun rises in the east, gets higher and higher in the sky and at noon reaches its highest point, then it begins to sink towards the west and finally disappears beneath the western horizon. In our hemisphere when the sun reaches its highest point it is exactly in the south; indeed, it is said to 'south,' and the shadows of all objects have then a true north and south direction. The interval of time which elapses between two successive southings of the sun is called a solar day and is divided into 24 hours. The stars may also be observed to rise in the east, to south or reach their highest point and to set in the west, and if a star be observed to south one night and to south again the following night the interval of time that elapses between these successive southings is called a sidereal or star day, and is 23 hours, 56 minutes, 4 seconds long.

From casual observations it would appear that the earth is immovable and that above it there is a large hollow globe in which the sun and stars are fixed, which imaginary globe turns slowly round the earth from east to west and causes the appearance of day and night; hence, when man argued that all the heavenly bodies were small and insignificant in comparison with the earth, and considered the world as an object by the side of which all others were unimportant, he concluded that it was immovable in the centre of the universe and that all the heavenly bodies revolved round it.

It can now, however, be shown that the moon is much nearer to the earth than the sun, that the sun is beyond comparison nearer to us than the nearest fixed star, and that some stars are infinitely more distant than others; hence it is impossible to imagine that all these bodies are moving around our little earth.

keeping their relative places unchanged. And since it is true that the appearance will be practically the same whether we consider that the earth is at rest and the heavens revolve round it, or that the heavens are fixed and the earth rotates on its axis like a top, it is easier to accept the latter supposition that the earth rotates on its axis in about 24 hours than it is to imagine that the whole universe revolves round the earth in the same time. The fact that either of these suppositions is sufficient to explain the observed phenomena was known to Ptolemy and the latter rejected by him. The honour of first proving to the world the true theory of the celestial motions belongs almost exclusively to a monk named Copernicus, who was born at Thorn, in Prussia, in 1473. The Copernican system was not published until 1543, and it is said that the author received the first completed copy when on his death-bed. One of the main principles of the theory is that the earth is not at rest but turns round on its axis from west to east once in rather less than twenty-four hours. This real motion of the earth causes the apparent motion of the celestial globe in an opposite direction, viz., from east to west. Copernicus showed how the movements of all the heavenly bodies could be explained by his theory, but was not able to substantially prove that the earth rotated, the only argument then known being that such a supposition was more probable than that the heavens themselves revolved.

After the invention of the telescope in 1608, it was found that the sun, moon, and planets all rotated on their shortest diameter or axis, and it was justly argued from analogy that the earth rotated also; but the analogy was not the proof. An objection raised against the Copernican theory was that the earth's motion is not felt. But against this it might be urged that the majestic rotation would not be felt any more than a sailor feels the motion of his ship in a placid sea. We will now, however, give observations which prove in a very tangible manner that the earth is in rotation.

In 1802 experiments were made at Hamburg which consisted of letting bodies fall from the top of a tower 250 feet high and observing the point where they touched the ground. It was found that the bodies had on the average a deviation of about a third of an inch towards the east. In 1831 an abandoned mine shaft in Saxony was used for the same purpose. The fall obtained in this case was 520 feet, and after a hundred experiments it was found that the average deviation towards the east was 1·12 inches. From these experiments, then, we learn that bodies dropped from the top of a high tower fall not at the foot of the tower but slightly to the east of it. The reason of this will be apparent from an inspection of Fig. 12. As the earth rotates in the direction indicated by the arrow,

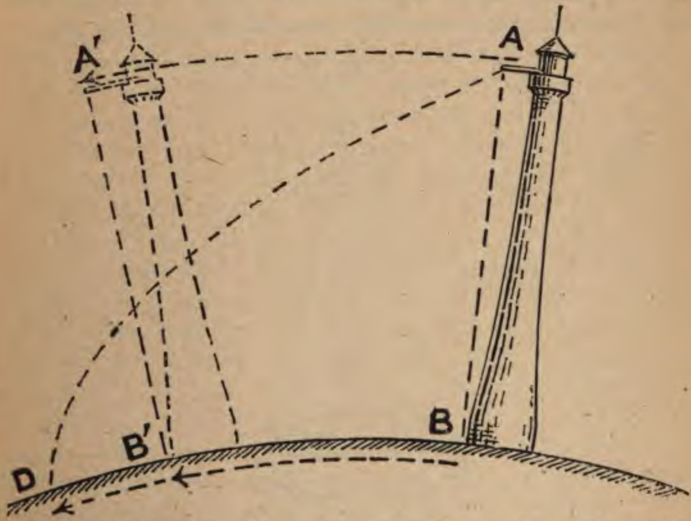


Fig. 12. Newton's experiment for proving the rotation of the earth. For simplicity the tower may be considered as on the equator. The earth would then appear to revolve in the direction indicated, when observed from above the northern hemisphere.

the top of the tower AB must move faster than the bottom because it has to describe a larger circle. A stone, therefore, at A has a higher velocity than the foot of the tower. Let the stone be dropped from the tower, and let the tower move from AB to A′B′ in consequence of the earth's rotation whilst the stone is falling to the ground. If the stone had remained at A it would have moved over the space AA′ whilst the foot of the tower was moving through the smaller amount BB′, and this excess of velocity which the stone possessed by virtue of a higher position causes it to fall at D, that is, eastward of the foot of the tower instead of falling exactly at the foot.

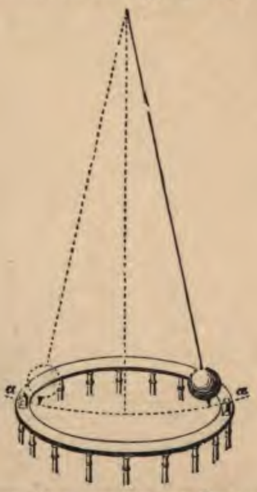


Fig. 13. Foucault's pendulum experiment for proving the rotation of the earth. The pendulum vibrates in a certain direction, *a a*. The circular table is slowly twisted under it, in the opposite direction to the hands of a watch, because of the earth's rotation.

This experiment was first suggested by Newton, but so many sources of error come in that it is not capable of giving very good results. Observers have found that the falling body does not invariably fall to the east of the tower but towards all points of the compass, and it is only by taking the average of a long series of experiments that any fairly reliable result has been arrived at.

Foucault devised and carried out an experiment in 1851 by means of which the rotation of the earth can be made visible (Fig. 13). A heavy iron ball, about a foot in diameter, was suspended from the dome of the Pantheon in Paris by a wire more than 200 feet long. The ball was held out of a vertical position by a thread, and when quite still the thread was burned and the ball thus let go. It was arranged that a small pin attached to the bottom of the swinging ball should trip and make a mark every time it passed a circular ridge of sand placed on the Pantheon floor. The experiment was made: at the first swing the pin made certain marks in the sand, the second pair of marks were slightly to the left of these, the third pair more so, and had the pendulum kept vibrating long enough, it would at length have cut all the sand away. What is the cause of this apparent displacement? Either the direction of the oscillations made by the pendulum is twisted round in the same direction as that of the hands of a watch or the floor turns under it in the opposite direction to watch-hands. Most people know that it is difficult to push a heavy body out of the path in which it is moving. Consider, then, the heavy pendulum bob described above; it is set vibrating in a certain path and cannot of itself move out of that path; hence it is inferred from the experiment that the floor and the roof of the building—and, therefore, the surface of the earth—moves from left to right under it. Foucault found by preliminary experiments that the path in which the pendulum vibrated remained fixed when the top of the wire by which it was suspended was twisted, and hence he argued that the motion of the top of the building did not affect the position of the path of vibration, the pendulum keeping in the path in which it was started as if it were not suspended from, or connected with, anything on the earth.

Such a pendulum suspended at either of the poles would appear to describe a circle in 23 hours, 56 minutes, 4 seconds, which, we have seen, is a sidereal day, or the true time of rotation of the earth. As we move from the poles to the equator the time taken for the pendulum to describe the circle increases, and at the equator no such motion is observed, the pendulum taking there an infinitely long time to complete the circle of vibrations.

Experiments with **Foucault's pendulum** have been made in various parts of the earth, and the time of rotation deduced from them is 23 hours, 53 minutes, 37 seconds, which differs from the true time by only 2 minutes, 27 seconds, and hence, is a very close agreement.

Another instrument devised by Foucault for demonstrating the rotation of the earth is called the **Gyroscope,** and consists of a heavy rimmed wheel mounted on gimbals so that it is free to turn in any direction. This wheel is set in rapid rotation in a certain direction, and keeps that direction unchanged in accordance with the law that no body has the power to alter its own state of motion. A microscope is arranged so as to watch a pointer over a graduated scale, and it is found that the pointer appears slowly to move from right to left, because of the motion of the microscope and scale from left to right.

A sketch of the instrument is shown in Fig. 14.

The above are some experimental proofs of the earth's rotation. We will now consider some phenomena which follow from it. In the first place a point on the equator has to be whirled through a distance of 25,000 miles in about 24 hours which, roughly speaking, is at the rate of a thousand miles an hour. At the poles, however, there is no rotation.

Suppose a cannon at the equator to be fired when pointing due north or south. If the earth did not rotate the ball would travel in a true north and south line; but on account of the rotation of the earth the ball, when it left the cannon's mouth, had a velocity of 1000 miles an hour from west to east as well as its northern velocity due to the combustion of the gunpowder. Thus the ball moves from a point where its velocity towards the east is 1000 miles an hour to parts of the earth where it is much less, and on account of this excess of velocity the ball deviates to the east of the direction in which the cannon was pointed. It will be seen later on that winds suffer the same deviation. Another consequence of the rotation is the shape of the earth itself. We have shown that the earth is flattened at the poles, and it can be proved that at one time our globe was in a viscous or semi-solid condition somewhat like thick tar. It has been shown by experiment, and proved mathematically, that a plastic body in rotation must assume the spheroidal shape described. All the particles of a rotating

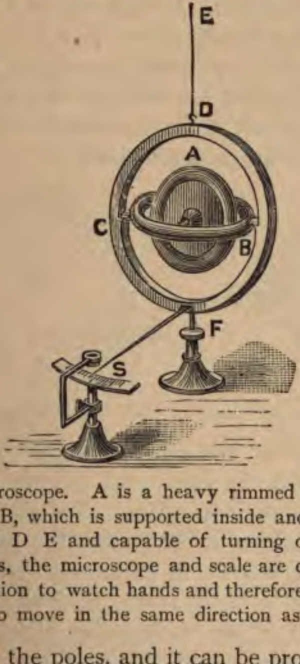


Fig. 14. A Gyroscope. A is a heavy rimmed wheel in rapid rotation in the ring B, which is supported inside another ring C, suspended by a thread D E and capable of turning on the point F. As the earth rotates, the microscope and scale are carried round in the opposite direction to watch hands and therefore the end of the pointer S appears to move in the same direction as watch hands.

mass tend to fly away from the centre of the mass; where the velocity is greatest this tendency is the strongest, hence the equator is bulged out because there the velocity of the particles is greatest, and a slight flattening occurs at the poles where the velocity of rotation is least.

We have now to investigate more closely the external apparent phenomena caused by the earth's real rotation.

It is easy to understand how objects may appear to move when they are really fixed. An observer in a railway train in motion sees everything outside flying past him in an opposite direction to that in which he is moving, and he knows that the appearance is produced by his motion. Similarly, our earth's rotation on its axis causes the appearance of movement of the heavenly bodies in an opposite direction.

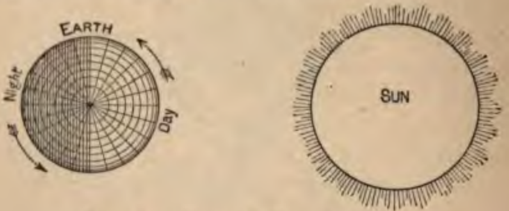


Fig. 15. Cause of Day and Night.

As a consequence of this rotation we get day and night. Let Fig. 15 represent the earth and the sun as seen if we were looking down upon it in space. The sun can only light up one half of the globe at one time, the other half being turned away from it will be in darkness. Hence, only one half of our earth can be lit up at one time and enjoying day, the other half will be in the darkness of night. Consider an observer in England at midday, with the sun overhead. As the earth rotates, other places are brought directly under the rays of our luminary, hence in about twelve hours the observer will arrive at a point opposite the sun and it will be midnight; and in about another twelve hours he will again have midday. Conceive the equator divided up into 360 parts and let a line be drawn from the north to the south pole through each of them. There will thus be 360 lines marked on the earth similar to those shown in Fig. 16. The direction of each line is exactly north and south, and any two of them exactly opposite each other form a great circle which divides the earth's surface into two halves or hemispheres. These lines are called **meridians of longitude.** At the equator the length of a degree is $\frac{1}{360}$th of the circumference of the earth or 69·1 miles. If this be divided up into sixty parts or minutes, the length of a minute is found to be 1·15 miles, and this length —that is, the sixtieth part of a degree on the equator—is called a knot or geographical mile. Hence, 60 geographical miles = 1 equatorial degree = 69·1 statute miles.

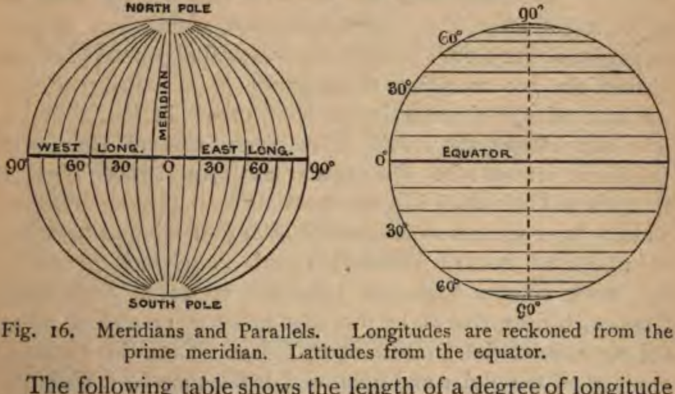


Fig. 16. Meridians and Parallels. Longitudes are reckoned from the prime meridian. Latitudes from the equator.

The following table shows the length of a degree of longitude in different latitudes.

Latitude.	Miles in 1° long.	Latitude.	Miles in 1° long.
0°	69	50°	44½
10	68	60	34½
20	65	70	23½
30	60	80	12
40	53	90	0

It is manifest from the foregoing that the sun will reach its highest point at the same time at all places on the same north and south line or meridian. When the sun reaches this point, which is approximately half-way between the eastern and western points of the horizon, it is said to be on the meridian; we then have noon or midday, and the time is 12 o'clock. The hours before noon are denoted by a.m. (ante meridiem), which signifies before the meridian, and hours after noon are distinguished by p.m. (post meridiem), meaning, after the meridian. Let the meridian passing through Greenwich Observatory be taken as the starting point, then there are 180 meridians of longitude conceived to be drawn upon the globe west of Greenwich, and 180 conceived to be drawn east of Greenwich, or 360 altogether. Hence 180° west longitude must coincide with 180° east longitude, and places on this meridian must be in midnight when it is Greenwich noon or midday. In consequence of the earth's rotation the sun will appear to pass over each of the 360 meridians of longitude in 24 hours, that is, at the rate of 15° degrees in an hour or 1° in four minutes. The sun crosses the meridian at places east of Greenwich before it crosses the Greenwich meridian, hence when it is noon at Greenwich it is afternoon at such places. Further, when it is 12 o'clock at Greenwich it is four minutes to twelve at places 1° west of Greenwich and 11 o'clock at places 15° west. Let a watch be regulated so as to keep exact Greenwich time, that is, let it always indicate 12 o'clock when the sun crosses the Greenwich meridian. Take the watch to any part of the globe and note what is the time by it when the sun reaches its highest point. If the time indicated by the watch when the sun was on the meridian be two hours after noon, then we should know that the sun crossed the Greenwich meridian two hours previously and since two hours of time are equivalent to 30° of longitude, we should be in a place 30° west or behind Greenwich. Hence, at any place west of Greenwich the watch would indicate time *after* noon and at any place east of Greenwich time *before* noon, when the sun crossed the meridian. For the purpose of determining longitude by this means, ships always carry one or more well regulated watches or chronometers keeping Greenwich time. It is, of course, immaterial which meridian is used as the standard of reference. The Greenwich meridian is the one adopted in Britain, Paris is the one adopted in France, and the Island of Ferro by Germany. Efforts have been and are being made to establish a universal meridian, but not with much success.

The following are some longitudes of towns expressed in angles and in the time equivalent to them:—

	Longitude.					
	In Angle.			In Time.		
Greenwich - - -	0°	0′	0″	0h.	0m.	0s.
Cambridge - - -	0	5	41 E.	0	0	22·8 E.
Dublin - - - -	6	20	30 W.	0	25	22 W.
St. Petersburg - -	30	18	22 E.	2	1	13·5 E.
Washington - - -	77	3	1 W.	5	8	12·1 W.
Calcutta - - - -	88	27	56 E.	5	53	52 E.
Pekin - - - - -	116	24	45 E.	7	45	39 E.
Melbourne - - -	144	58	42 E.	9	39	54·8 E.
Antipodes Isle - -	179	30	0 E.	11	58	0 E.

When a place has east longitude the above times represent the amount by which local time is ahead of Greenwich time; and when a place has west longitude, local time is a certain amount behind Greenwich time. Perhaps the most striking example of difference of longitude is brought out by means of the electric telegraph. The time taken for telegraphic messages to travel any distance on the earth may be taken as nothing. If, therefore, a signal be sent from Greenwich at noon any day to Calcutta, although it travels instantaneously, yet it is nearly six o'clock in the evening local time when it arrives there, and a telegram sent to Dublin at Greenwich noon reaches there about 11.30 a.m., local time.

When it is midnight at Greenwich it is midday at places on the meridian 180°. But places so situated may be considered to be 12 hours in advance of Greenwich in point of time, or 12 hours behind it, according to whether its longitude is reckoned as 180° E. or 180° W. Hence in going round the world from east to west, on reaching meridian 180° the time is 12 hours ahead, whilst in travelling from west to east to the same meridian 12 hours are apparently gained. If, therefore, a voyage be made round the world from London, 24 hours are apparently lost in sailing west by America and the same amount gained in sailing east by the Suez Canal. In the first case, if it were Monday on board the ship when it arrived in dock, it would be Tuesday in London; in the second case, Monday according to the travellers' reckoning would be Sunday in London. In order to remedy this, when vessels cross meridian 180° a day is added if the vessel sailed from the east, or dropped if it sailed from the west.

GENERAL SUMMARY OF CHAPTER III.

The daily motion of the heavens from east to west is only an apparent motion, and is caused by a daily rotation of the earth from west to east on its shortest diameter.

Experimental proofs of the earth's rotation :—

(1). Bodies falling from a great height deviate towards the east.
(2). Foucault's pendulum experiment.
(3). Foucault's gyroscope.

Consequences of the earth's rotation :—

(1). Bodies moving from the equator to the poles are deviated towards the east.
(2). The shape of the earth is that which would result from the rotation of a semi-fluid mass.

Day and Night occur as the rotation of our globe causes one half to be turned towards the sun and to be in light, while the other is turned towards the stars and in darkness.

Meridians, or Lines of Longitude are semi-circles supposed to be drawn on the earth's surface from the North to the South Pole through any place. They are generally reckoned up to 180° W. and 180° E. of Greenwich, but any meridian may be taken as the starting point.

The sun passes over 360 meridians of longitude in 24 hours, hence, the **Relation between Longitude and Time** is:—

Longitude.	Time.
1°	4 minutes
15°	1 hour
90°	6 hours
180°	12 hours

The local clock at the western station marks an earlier hour than that at the eastern station.

To Determine the Longitude of a Place:—Compare the local time, as determined by the sun's position, with the time shown by a chronometer keeping Greenwich time, or: Note the interval of time that elapses between the meridian passage of the sun and the receipt of a telegraphic signal from an observer in direct communication, stating that the sun had just passed his meridian. When this time interval is known, the difference in longitude may be calculated by means of the relation given above.

CHAPTER IV.

REVOLUTION OF THE EARTH AND CONSEQUENT PHENOMENA.

BESIDES the daily or diurnal phenomena, which occur in consequence of the rotation of the earth, other annual phenomena have been observed from the earliest ages. In the first place, the path described by the sun across the heavens is not always the same, and in the summer our luminary describes a larger arc and is higher in the heavens at midday than it is in the winter (Fig. 17). Again, if we observe the stars which set shortly after the setting of the sun, we shall find that in the course of a few days they will no longer be visible, and other stars, which previously did not set till long after the sun, now accompany him. Similarly, the stars which appear at one time near the sun when it is rising are, after a few days, considerably elevated above it at the same time. These appearances are, however, periodic. The stars which set soon after the sun in the spring will be found to occupy exactly the same relative appearance in the following spring, and those stars which accompany the sun in the autumn will again be found to accompany him in the following autumn. This regular succession of annual phenomena has, of course, been long utilised by man to measure time, and hence the greater part of the observations of early astronomers had for their object the determination of the positions of the stars relatively to the sun at his rising and setting, by which they fixed the seasons and regulated the operations of agriculture.

In addition to the difference in relative position of the sun and stars in different seasons, it may be noted that different groups of stars, or constellations as astronomers call them, appear in the midnight sky at different times of the [illegible] nted by other groups, and at the same time in the following year are found in the same position. Thus, in England, an observer might notice a particular star exactly over a particular point on the earth at midnight. A few nights after, the star will no longer be found to occupy the same position at midnight; the distance from the midnight point first observed will go on increasing, night by night, until, as the season returns in which the first observation was made, the star will approach its original position, and on a particular night will be found again to occupy exactly the same position that it did previously. The interval of time that elapses between these two successive appearances is called a sidereal year—a year measured by the stars. It appears,

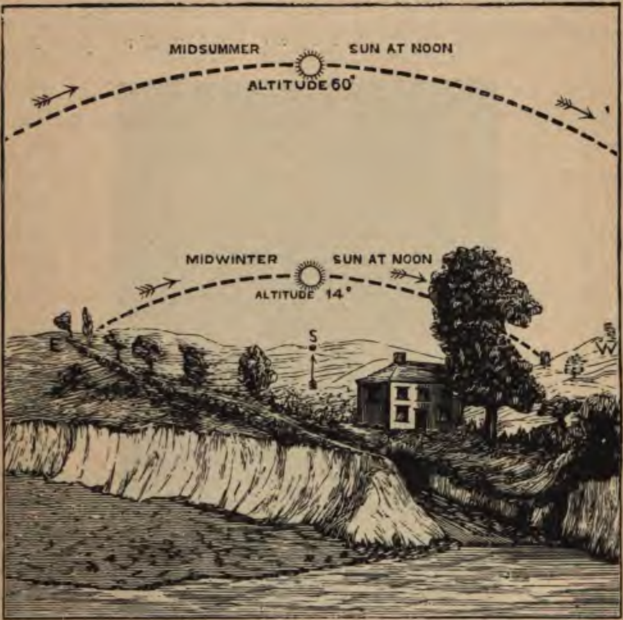


Fig. 17. The difference in the Altitude of the Summer and Winter Sun in the latitude of London.

therefore, that the sun has an apparent easterly movement amongst the stars which it takes a year to accomplish. What is the cause of this yearly series of phenomena? We have shown that the earth rotates—has it another motion? The answer to the question and the explanation of the phenomena lie in the fact that the earth moves round the sun from west to east once a year. This revolution causes the apparent motion of the sun among the stars. Pythagoras, so long ago as 500 B.C., is supposed to have propagated the doctrine of the earth's revolution round the sun. Ptolemy, however, placed the earth in the centre of the universe, and supported his complicated and cumbrous theory by ingenious reasoning. The doctrine of the earth's superiority over all other bodies in the universe had

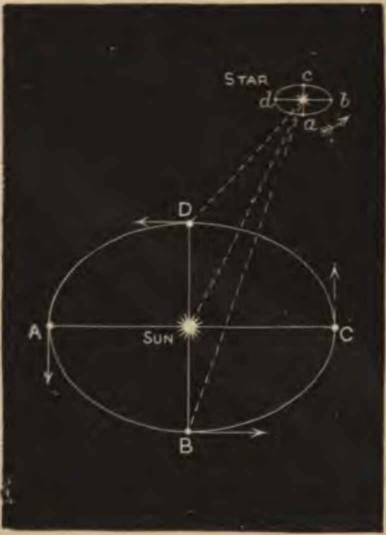


Fig. 18. Aberration Ellipse. When the Earth is at A, B, C, and D the star appears to be at a, b, c, and d, that is, in advance of its true position, owing to the motion of the Earth.

been accepted from the time of Ptolemy, 130 A.D., when Copernicus published his theory in 1543, which placed our earth in a very minor position as one amongst other bodies or planets revolving round the sun as a centre; and it is this theory of the revolution of the earth round the sun that best explains the apparent motion of the sun, moon, and planets amongst the stars. The telescope has brought to light two very minute phenomena which prove that the earth revolves round the sun. One is the **aberration of light.** An idea of its nature may be understood from an analogy. Suppose rain is falling straight down, as we sometimes see it. An umbrella has to be held exactly overhead to shield off the drops, when we stand still; when, however, we begin to walk the umbrella has to be tilted forward to catch the drops, and must no longer be held vertically; the faster we walk the more must the umbrella be tilted forward, and the rain no longer appears to fall straight down from the clouds but to fall slantingly and in advance of its true position. Similarly, if the earth were at rest, then a star in the zenith would always be seen in the same position; but, because the earth moves around the sun, a telescope has to be tilted a very small amount in order to see the star, and, as was the case with the umbrella, the tilt will always be in the direction of the earth's motion. The amount of slant of tilt is about 20″ and is called the *constant of aberration*. A star may be observed by means of delicate instruments, say in December of any year: it appears exactly above a plumb line, that is, in the zenith. In March it is 20″ to the south of its former position, in July it has returned to the zenith, from July to September it moves towards the north and in the latter month is 20″ north of the zenith, after this it slowly returns and in the following December is again in the zenith. It thus takes a year to complete this cycle, and it is found that it always takes any particular star 365 days to traverse its apparent path and return to the same point again. This will be understood from Fig. 18.

Thus the aberration of light enables it to be proved beyond doubt that the earth has a motion of revolution in addition to that of rotation.

Another proof of the earth's revolution is found in the fact that some of the stars, though at enormous distances from us, nevertheless appear to change their position. To understand the reason of this, let us conceive a circular railway constructed upon a level plain (see Fig. 19). The earth may be considered to travel in a path round the sun similar to an engine moving on the circular railway. When the engine is at A an observer focuses a telescope upon a church tower; or some object at a considerable distance. Let the engine move round to B, the observer will now have to turn his telescope back through a certain angle in order to see the tower, when he arrives at A again he will have to direct his telescope as formerly, so that, because of the motion of the engine in the railway, the position of outside objects undergoes a change, due to the varying positions of the observer. The stars are at such enormous distances from the earth, that the diameter of the path in which it revolves round the sun is almost as a point compared to their distances, and, hence, the light from a star as seen from two positions on the earth's path nearly opposite one another is almost exactly in the same direction. With the increase of delicacy of astronomical instruments, however, it has been found that a star observed at one time appears in a slightly different position about six months later, when the earth is on the other side of its path, or orbit as it is called.

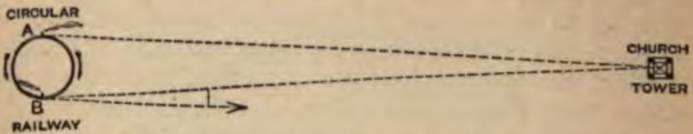


Fig. 19. The change in the apparent direction of an object as the position of the observer is altered.

This difference in apparent position of the star, known as the **Annual Parallax,** may therefore be considered as another proof of the earth's revolution.

We will now consider the observations which enable us to decide the exact shape of the path in which the earth revolves round the sun. Daily measurements of the sun's diameter show that it gradually increases from July to January and then decreases from January till July. The diameter of the sun on January 1, 1890, was 32′ 36¼″, whilst its diameter on June 30 was 31′ 32″. Only one deduction can be drawn from this, viz., that the earth is nearer the sun in January than in July. It is evident that these variations could not occur if the path in which the earth moves round the sun were circular, for then our luminary would always appear exactly the same size when measured at noon every day throughout the year. By investigating the series of measurements, astronomers have been able to determine that the shape of the earth's orbit is that of an ellipse. It was shown in the first chapter that every ellipse has two foci, and it has been found by the above method that the sun occupies one of the foci of the elliptical path traversed by the earth in its revolution. In January the distance of the earth from the sun is 90,436,000 miles, in July 93,564,000 miles; hence, since winter occurs when the earth is nearest the sun in point of distance, and summer when it is farthest away, some other circumstance must be found to explain the varying seasons.

Consider again the path of the earth represented by an elliptical but very nearly circular railway on a level plain, and let an electric light be fixed in the ellipse to represent the sun. The engine will travel round the electric light always on the same level or plane. Transfer your thoughts from the imaginary engine and the electric light to the earth and sun in space. The earth travels round the sun in one plane, on one level, as definitely fixed as was the plane in which the engine moved round the electric light. It does not bob up and down, but floats round the central body like a ship in a perfectly placid sea. This plane in which the earth performs its revolution is called the **plane of the ecliptic.** If the earth floated upright in the ecliptic plane, the equator would coincide with it, and the axis would be at right angles to it. Summer would then occur when the earth was nearest the sun, and all over the earth our luminary would cross one particular path in the sky, and would attain at midday a certain altitude which, although different for different latitudes, would always be the same for the same latitude. But the earth does not float upright in the ecliptic plane, and hence the sun does not appear to describe the same arc in the sky throughout the year.

The majority of people have observed that the shadows of all objects decrease in length from sunrise to noon and then increase to sunset, and it is fairly evident that shadows are shortest when the sun is highest in the sky. If a post be fixed in the ground, the length of its shadow, measured at noon throughout the year, will be found to decrease from spring to summer, to reach a shortest length and appear to have the same length for several days, to increase in the autumn to the length measured in the spring, and in the winter to be much longer than in summer. (Fig. 20.)

As an example of the great difference in the length of the shadow it may be mentioned that the Eiffel Tower, which is 984 feet high, has a mid-day shadow 3,060 feet long in December, and 478 feet long in June, the difference being 2,582 feet. It is evident from the accompanying figure that the angular distance of the sun from the zenith, and therefore its altitude or angular distance from the horizon, may be determined by these means. A column erected perpendicular to the horizon for the purpose of determining the altitude of the sun is called a **gnomon,** and it is known that many of the Egyptian obelisks were erected primarily to serve as gnomons. Indeed, such observations as the above described have been made from time immemorial, and careful measurements show that from spring to summer the sun describes arcs of increasing size, and on midsummer day at noon is 23½° higher than it was at noon in mid-spring. It then appears to describe the same arc for a few days, and little change is perceptible in its midday altitude. This point is called the **Summer Solstice,** because the sun appears to stand still. From midsummer day, however, the sun gradually describes lower arcs, and in autumn has returned to the point it occupied in spring.

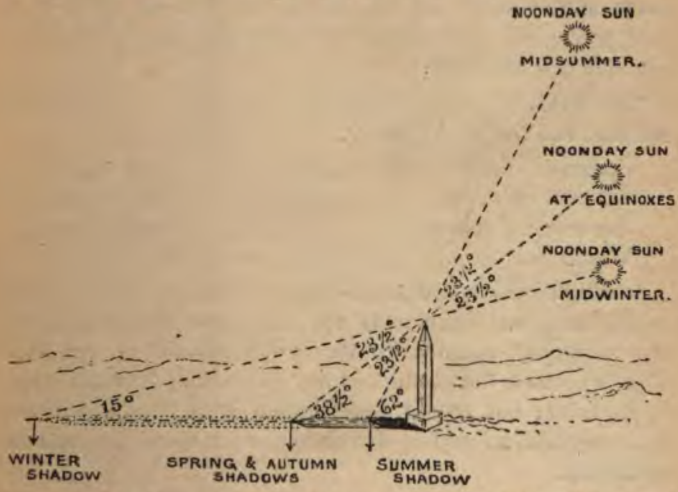


Fig. 20. The Gnomon. Method by means of which the Obliquity of the Ecliptic (23½°) may be determined. The altitudes given are for the latitude of London.

At these times the days and nights are everywhere of equal length and the earth is said to be at the **Spring and Autumnal Equinox** respectively. From autumn to winter the sun's altitude at noon decreases, and in midwinter is 23½° below the spring and autumn points. Again there is the appearance of standing still, and the earth is said to be at the **Winter Solstice.** After midwinter day the sun describes arcs of gradually increasing size until the summer.

When the arcs described by the sun are increasing in size, that is from winter to summer, our luminary is apparently moving towards the north; as they decrease in size it moves southward. These changes can be determined by observing the points on the horizon at which the sun rises and sets during different times of the year. In London at the summer solstice the sun rises about forty degrees north of the east point, at the winter solstice about forty degrees south of the east point, and it is only at the equinoxes that it rises and sets due east and west.

The dates at which the earth passed the equinoxes and solstices in 1890 are as follows:—

Spring or Vernal Equinox	...March 20.	Spring begins.
Summer Solstice... ...	...June 20.	Summer begins.
Autumnal Equinox ...	...Sept. 23.	Autumn begins.
Winter Solstice	...Dec. 21.	Winter begins.

It will be observed that the interval from the vernal equinox to the autumnal equinox is 187 days, and the interval from the autumnal equinox to the vernal equinox is 178 days. This is because the earth does not move with uniform speed in its orbit; but moves fastest when it is nearest the sun or at **perihelion** and slowest when it is most distant or at **aphelion.**

The foregoing observations prove that the plane of the earth's equator makes an angle of $23\frac{1}{2}^\circ$ with the plane in which it revolves round the sun; the axis is therefore inclined $90^\circ - 23\frac{1}{2}^\circ$ or $66\frac{1}{2}^\circ$ to the same plane. The angle contained between the two planes is termed the **Obliquity of the Ecliptic.** It is constant all the year round; hence, as the earth revolves round the sun, the northern and southern hemispheres are alternately turned towards our luminary and turned away from it (Fig. 21). It is to this inclination of the earth's axis that we have to refer the cause of the seasons. When we have summer in the northern hemisphere, the sun rises high in the sky and radiates its light and heat directly down upon us. The people in the southern hemisphere then have winter, because they are turned away from the sun. When however, six months later, winter occurs in the northern hemisphere, then summer occurs in the southern hemisphere. At the equinoxes the sun is directly over the earth's equator and appears midway between the highest and lowest points reached by it in a year. This is because when the earth is at either of these points it is neither turned towards the sun nor turned away from it, but is lit up as shown in Fig. 22. It requires a little consideration to understand why the high suns of summer and the low suns of winter should have such effect upon the temperature of our globe. The atmosphere surrounding our globe stops much of the sun's light and heat, and therefore the greater the thickness of atmosphere traversed the less is the amount received.

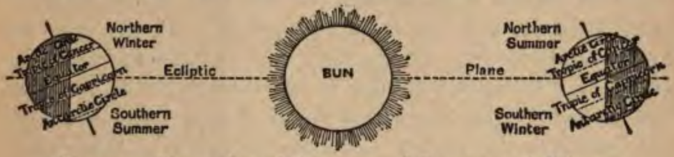


Fig. 21. Illustration of the cause of Summer and Winter.

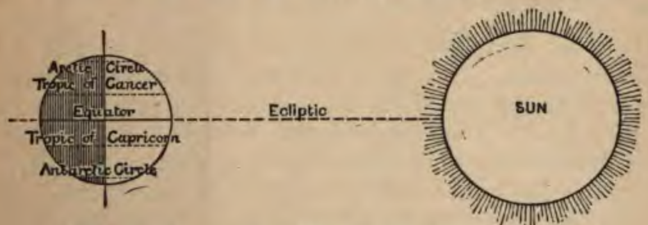


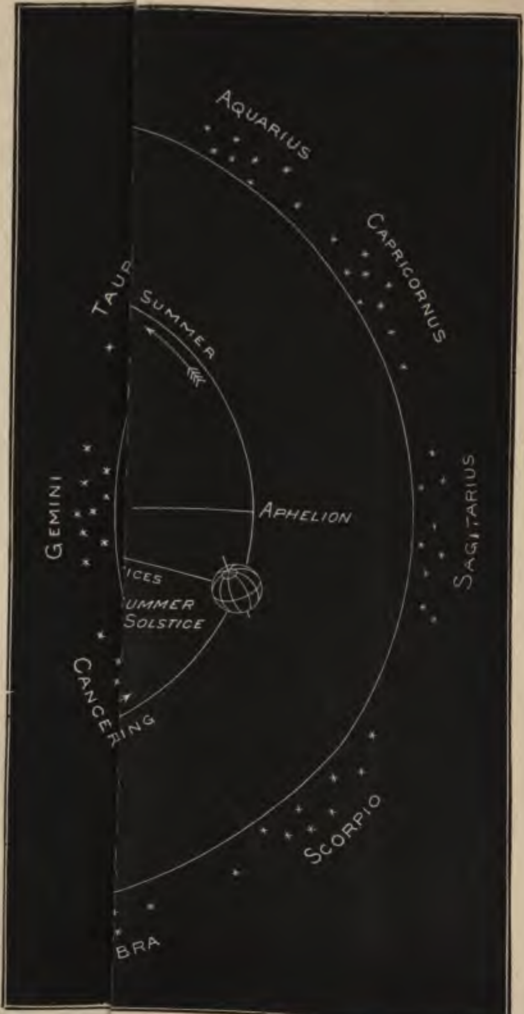
Fig. 22. Appearance of the Earth at the Equinoxes.

When the sun's rays are passing almost vertically through the atmosphere the greatest amount of light and heat are received. As the rays become less and less vertical, however, more and more light and heat are absorbed by the atmosphere, and less received at the earth's surface. In addition to this we have the fact, that when it is summer in the northern or the southern hemisphere the sun describes a larger arc and the days are consequently longer; hence, more heat is received in the day than is lost at night. In the winter the reverse is the case. The earth thus gets hotter and hotter during summer, cooler and cooler in the winter. This accumulation of heat causes the highest summer temperature to occur not when the sun rises highest in the sky on midsummer day, but on July 26. For a like reason, the lowest temperature does not occur on midwinter day, but on January 14. Similarly, the mean temperatures of the year do not occur at the equinoxes, but on April 24 and October 21 respectively.

The earth and its orbit are represented in Fig. 23, but it should be remembered that the dimensions of the orbit are as nothing compared with the immense distances of the stars that surround our little system on all sides.

Consider the plane of the ecliptic produced to meet the celestial sphere. The sun in its annual motion will appear to travel along the line where they intersect—it will always be in the ecliptic. The groups of stars, however, which form the background of the sun will be different at different periods of the year. Early astronomers divided the apparent yearly path of the sun among the stars into twelve parts, and the groups of stars extending about eight degrees above and below the ecliptic were called **Signs of the Zodiac.** The names of the signs are:—

♈ Aries	the Ram	Spring Signs.
♉ Taurus	the Bull	
♊ Gemini	the Twins	


AQUARIUS
CAPRICORNUS
TAU
SUMMER
SAGITARIUS
GEMINI
APHELION
ICES
UMMER
SOLSTICE
CANCER
ING
SCORPIO
BRA

Space.

♋ Cancer	the Crab	Summer Signs.
♌ Leo	the Lion	
♍ Virgo	the Virgin	
♎ Libra	the Balance	Autumn Signs.
♏ Scorpio	the Scorpion	
♐ Sagittarius	the Archer	
♑ Capricornus	the Goat	Winter Signs.
♒ Aquarius	the Water-bearer	
♓ Pisces	the Fishes	

In the time of Hipparchus (B.C. 150), the line joining the two equinoctial points pointed in one direction to the constellation Aries, in the other to Libra. When this was the case, the sun entered Aries at the spring equinox, Cancer on midsummer day, Libra at the autumnal equinox and Capricornus on midwinter day. The point in the sky occupied by the sun at the spring equinox, that is, one of the points where the plane of the ecliptic intersects the plane of the equator, is taken as the starting point for reckoning the longitudes of stars in the same way that the meridian at Greenwich is taken as the starting point for measuring terrestrial longitude. Owing to a cause which it is beyond the province of this work to explain, the line joining the **equinoctial points or nodes** does not constantly point in the same direction, and now, instead of pointing to Aries, it points to Pisces. Hence, the sun is now in Pisces at the spring equinox, near Gemini at the summer solstice, in Virgo at the autumnal equinox, and near Sagittarius at the winter solstice. This movement of the equinoctial points round the ecliptic is called the **precession of the equinoxes**. It amounts to about 50″ per annum, so that a revolution is completed in about 26,000 years. But, notwithstanding the fact that the equinoctial line no longer points to Aries, astronomers still call the position of the sun at the spring equinox the **First point of Aries** and count the longitudes of stars from it. The equinoctial points or nodes mark the intersection of the plane of the earth's equator with the plane of the ecliptic. They move round the ecliptic plane once in about 26,000 years, hence the north and south poles of the earth, and the celestial poles, which are above them, also move round the north and south poles of the ecliptic in the same time; and hence if we imagine an observer living on the north pole of the earth for the period of 26,000 years, he would see our present pole star get further and further away from the zenith in centuries of observation, and other stars would take its place. Another effect of precession is to alter the seasons which occur when the sun occupies a certain position in the heavens. We have seen that the cause of the seasons is the inclination of the plane of the earth's equator to the ecliptic plane, and it will be understood from the accompanying figure that in 13,000 years summer will occur at that point of the orbit which the earth now occupies at winter. Similarly all the seasons are, so to speak, slowly moving round the earth's orbit. In 13,000 years the sun will be projected upon the constellation Virgo at the spring equinox; spring will occur when the earth is in that portion of its orbit which it now occupies at autumn; and summer and winter will have changed places.

The ancients observed that when the sun had attained its greatest declination, 23½° from its equinoctial position, it began to go back towards the equator; and the Crab having been supposed to move backwards, his name, Cancer, was given to the constellation occupied by our luminary before it turned to go back. The naming of the constellation occupied by the sun, when at its greatest south declination, is still more fanciful. It was supposed that the goat, after ascending the hill as he feeds, turns back again on reaching the top. The analogy was applied to the sun, and the constellation in which he appeared at the winter solstice was therefore named Capricornus.

It is evident that as the sun in a year travels 23½° north and 23½° south of the equator, it must stand vertical twice each year over every portion of our globe which lies between these limits of latitude. This belt, 47° in width, is called the **Torrid Zone**, and the lines bounding it are called **Tropics** because the sun appears to 'turn back.' In it the days and nights are nearly uniform throughout the year. From the foregoing it will be understood why the north parallel of latitude is called the **Tropic of Cancer,** and the south parallel the **Tropic of Capricorn.**

We have previously shown that when the sun or a star is in the zenith of an observer at the equator, it is theoretically just on the horizon of an observer at either of the poles, that is to say, the sun is visible at places within about 90° of the place where it is in the zenith. This being so, when our luminary is on the tropic of Capricorn in 23½° south latitude, he is just on the horizon of an observer in a latitude 90° distant, that is, in 66½° north latitude; while all places still further north do not see him at all. Similar reasoning applies to the case when the sun is on the tropic of Cancer. The parallels of latitude 90° away from the tropic of Capricorn and the tropic of Cancer are respectively called the Arctic and Antarctic Circles, and the two regions round the poles bounded by them, and therefore embracing 23½° of north and south latitude, are known as the **North and South Frigid Zones.** In these regions, at least one day occurs in a year when no sun is seen during an entire rotation of the earth. The belt extending from either tropic to the corresponding polar circle, that is, from 23½° to 66½°, is called the **Temperate Zone.** In this zone there is always true day and night, but the lengths vary and are dependent upon the latitude.

The following are the lengths of the longest and shortest days in a few latitudes:—

Latitude.	Longest Day.	Shortest Day.
0°	12 hours 0 mins.	12 hours 0 mins.
10°	12 „ 35 „	11 „ 25 „
20°	13 „ 13 „	10 „ 47 „

Latitude.	Longest Day.		Shortest Day.	
30°	13 hours	56 min.	10 hours	4 min.
40°	14 ,,	51 ,,	9 ,,	9 ,,
50°	16 ,,	9 ,,	7 ,,	51 ,,
60°	18 ,,	30 ,,	5 ,,	30 ,,
66½° (Arctic Circle)	24 ,,	0 ,,	0 ,,	0 ,,
70°	2 months			
80°	4½ ,,			
90° (Pole)	6 ,,			

By reference to previous figures and the descriptive text it will be understood why the sun does not rise at the poles for about six months, and when it does rise is visible for about six months.

GENERAL SUMMARY OF CHAPTER IV.

The Motions of the Earth are :—

(1.) Rotation on its shortest diameter causing Day and Night.

(2.) Revolution round the sun causing Seasons.

(3.) Motion of the axis round the pole of the ecliptic called Precession.

The Earth revolves round the Sun while it is making about 365¼ rotations on its axis.

Proofs of the revolution of the earth :—

(1.) **The Aberration of Light.** Owing to the motion of the earth combined with the velocity of light stars appear 20″ ahead of their true positions.

(2.) **The Annual Parallax of fixed stars,** *i.e.*—some of the stars appear in a different direction when viewed from two opposite points on the earth's orbit. The true annual parallax of a star is the angle contained between two lines to the star, one drawn from the centre of the earth's orbit, the other from a point on the orbit.

The Orbit of the Earth is Elliptical in Shape, and the sun occupies one of the foci. This has been determined by accurately measuring the sun's diameter throughout the year. In consequence of the form of the orbit the earth is about three million miles nearer the sun in winter than in summer.

The Plane of the Ecliptic is defined by the path the centre of the earth describes round the sun. The axis of the earth makes an angle of 23½° with a perpendicular to this plane. This is therefore the angle contained between the ecliptic plane and that of the equator. The two points where the ecliptic cuts the plane of the equator mark the two equinoxes (equal night points). The two points on the ecliptic most distant from the equinoctial points mark the solstices (standing points of the sun).

The Summer and Winter Solstices are the times of the year when the sun reaches its greatest northerly and southerly declinations and appears to describe the same arc for a few days.

The Spring and Autumn Equinoxes are the times of the year when the days and nights are equal all over the world and the sun is on the celestial equator.

The Obliquity of the Ecliptic is the angle between the plane of the ecliptic and that of the celestial equator.

The Succession of the Seasons depends upon the revolution of the earth, and also upon the inclination of its axis. It is hotter in summer than in winter, because (1) the sun is more nearly vertical; (2) because the days are longer than the nights.

The Ecliptic is the apparent annual path of the sun among the stars.

The Zodiac is a belt encircling the heavens about eight degrees on each side of the ecliptic. In the older astronomy it was divided up into twelve parts called *signs of the zodiac.*

The Precession of the Equinoxes is a motion of the equinoctial points around the ecliptic, taking about 26,000 years to complete a revolution. In consequence of this movement, the signs of the zodiac do not coincide with the zodiacal constellations.

The Tropic of Cancer is the circle in the northern hemisphere over which the sun is vertical on midsummer day, and is therefore 23½° north of the equator.

The Tropic of Capricorn is a similar circle lying 23½° south of the equator.

The Arctic Circle borders the area of land around the North Pole which is not lit up by the sun on midsummer day for twenty-four hours; it is therefore 66½° north of the equator.

The Antarctic Circle is the line bordering a similar area extending 23½° from the South Pole.

Zones. The earth may be divided into five belts, or *zones*. The *torrid or hot zone* extends from the tropic of Cancer to the tropic of Capricorn. The *two temperate zones* extend from the tropics of Cancer and Capricorn to the Arctic and Antarctic circles respectively. The *frigid or cold zones* include the regions within 23½° from either pole.

CHAPTER V.

THE SUN AND PLANETARY SYSTEM.

THE countless stars with which the celestial world is sprinkled move together like bright spots upon a solid revolving sky. From their fixed relative positions they have been called *fixed stars.* At certain times objects are seen which do not remain fixed among the stars from night to night. The ancients knew five such objects and called them planets, that is, wandering stars. Other stars frequently appear in the sky accompanied by a luminous cloud or tail; these are called comets. They travel in all directions, and have much more erratic movements than the planets.

It was suspected in very early times that the movements of these wandering objects had a sort of relationship to the movement of the sun in the ecliptic. The cause of the relationship is now understood. Planets and comets revolve round the sun in elliptical orbits in a similar manner to the earth; thus the earth is only one of a family depending on our central luminary for light and heat, and the whole group is called the solar system. This system is entirely distinct from the star systems that occur in the heavens at an immense distance away.

The sun is by far the largest and most important body in our system. Its diameter is 860,000 miles, so that 108 earths would just about stretch across it. The volume of our luminary is about 1,300,000 times that of the earth, but since the materials of which it is made up are only $\frac{1}{4}$ as heavy as those constituting the earth, about 325,000 earths would balance the sun. As an illustration of the great diameter of the sun, it may be noted that the moon revolves round the earth in an orbit at a mean distance of about 240,000 miles, and if it were possible to place the earth at the sun's centre and the moon at its proper distance from the earth, our satellite would only reach half way to the sun's circumference (Fig. 24). From observations of spots which may often be seen on the sun by means of a telescope provided with a dark glass, it has been found to have a period of rotation of about twenty-five days. It results from the rotation that a spot is visible for about a fortnight and then invisible for about the same time. These spots are most probably hollows in the brilliant surface of the sun called the photosphere, and investigations show that they are produced on a portion of the sun's

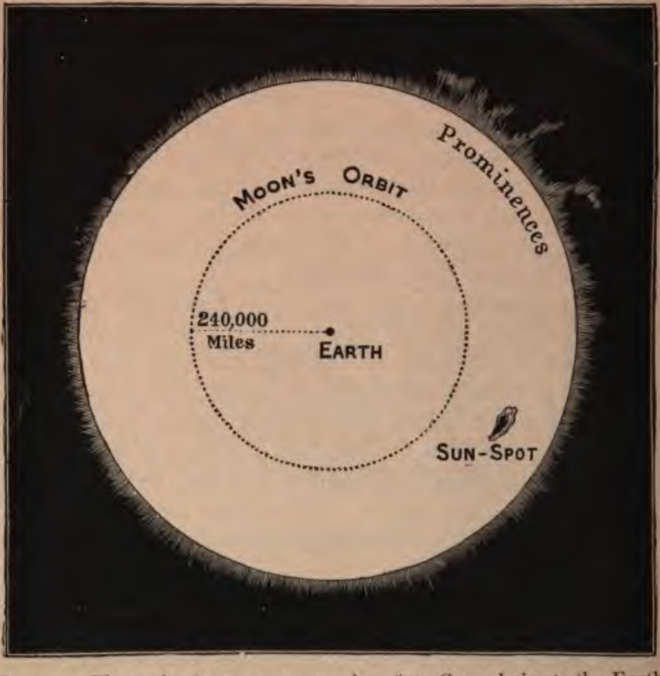


Fig. 24. Illustration of the enormous size of the Sun relative to the Earth.

surface comprised in two bands, situated between latitudes 10° and 35° north and south of the solar equator.

The spots change continually in form and in size and have a slight motion of their own in addition to the motion of rotation. Their duration varies from a few days to two months. The number of spots that occur upon the sun show very pronounced differences in different years, or, in more scientific language, have clearly marked maxima and minima. During some years scarcely a day passes without a spot or groups of spots being seen; at other times weeks and months may pass without a spot being visible. About eleven years separate two consecutive maxima or two minima, and a period of about five years occurs between a maximum and a minimum, or *vice versa*. The last maximum in the occurrence of sun spots was in 1883, the last minimum in 1889. Remarkable disturbances upon the sun are followed by magnetic disturbances upon the earth; delicately suspended compass needles oscillate about their true position, and auroras are more frequent. It is however not surprising that a connection exists between the sun-spot period and disturbances in our atmosphere and upon the earth; in fact, observations have shown that the amount of rainfall in India is subject to an eleven-year period of variation, and famines in India have been found to occur in years of drought coincident with periods of minimum sun-spots, whilst it has been asserted that trade is subject to similar periods of depression; but these connections have not been abundantly confirmed. There is, however, little doubt that the frequency of auroras and of magnetic disturbances is subject to a period corresponding to that of sun spots, these occurrences being most frequent when the spots are most numerous.

The sun has been radiating light and heat into space for thousands, or even millions, of years. Its temperature was once much higher than it is now, but even now it is much hotter than the hottest fire. If we calculate how much the temperature of the sun would be decreased annually by the radiation from his surface, we find it to be from 5 to 10 degrees. At this rate our luminary would cool right down to the temperature of the earth in a few thousand years. Two theories have been propounded to account for the heat that must be set up in the sun to keep its temperature so nearly constant. One is that the small bodies swarming in space, and called meteorites, clash against our luminary and increase the temperature by impact upon its surface. This however will only account for a small portion of the sun's heat, and the theory generally accepted is that the ball of luminous matter generates enough heat by its contraction to make up almost the entire loss. In fact, it has been calculated that the contraction which would reduce the sun's diameter $\frac{1}{10000}$th part would generate sufficient heat to last for 2000 years.

The ancients distinguished and called planets five bodies which moved among the stars, and named them Mercury, Venus, Mars, Jupiter, and Saturn. They also called the Sun and Moon planetary bodies. The moderns do not count the Sun and Moon as planets, but have added to the above list two faint bodies barely visible to the naked eye, and called them, respectively, Uranus and Neptune, besides a host of minor planets or asteroids. All the planets revolve round the sun in one invariable direction, which, if we could view them from above the plane of the ecliptic, would be seen to be opposite to that of the hands of a watch; each planet also rotates on an axis in the same direction. In order to see the motion of the planets in their greatest simplicity, the student should conceive himself stationed at the sun. The stars would be seen fixed in the heavens at an infinite distance away, and the planets would be observed to move among them.

The following illustration by Sir John Herschel gives some conception of the relative sizes and orbits of the planets:—
‘Choose any well-levelled field. On it place a globe two feet

in diameter; this will represent the sun. Mercury will be represented by a grain of mustard seed, on the circumference of a circle 164 feet in diameter for its orbit; Venus, a pea on a circle of 284 feet in diameter; the Earth also a pea on a circle of 430 feet; Mars, a rather large pin's-head on a circle of 654 feet; the asteroids, grains of sand in orbits of 1000 to 1200 feet; Jupiter, a moderate-sized orange in a circle of nearly half a mile across; Saturn, a small orange on a circle of four-fifths of a mile; Uranus, a full-sized cherry or small plum upon the circumference of a circle more than a mile and a half; and finally Neptune, a good-sized plum on a circle about two miles and a half in diameter.' On this scale the nearest star would be 8000 miles away.

We have before noted that the plane of the earth's orbit is called the plane of the ecliptic. The orbits of all the planets are not exactly in the same plane, that is, the planets do not all revolve round the sun on exactly the same level. The orbits of the planets (not reckoning the asteroids), lie in planes within 8° on either side of the plane of the ecliptic. It is evident, therefore, that no planet can be seen more than 8° above or below the ecliptic. The ancients observed that this was the case and accordingly assigned a width of about 8° above and below the ecliptic to the zodiac. The axis of each planet—that is, its shortest diameter—is inclined to the plane of its orbit at a constant angle, which differs, however, in each of them. It will be remembered that the axis of the earth is inclined 66½° to the plane of the ecliptic.

Revolving round all the planets except Mercury, Venus, and the asteroids are bodies called satellites or moons. Of these the earth has one (the moon), Mars has two, Jupiter four, Saturn eight, Uranus four, and Neptune one. Some explanation of this motion of revolution is necessary. If a very heavy weight (B) is fixed at one end of a rod, and a light weight (A) at the other, it is known that the balancing point would be much nearer the former than the latter. (Fig. 25.) This point is called the **Centre of Gravity.** Although no rod joins the earth to the sun the same law prevails, and since the sun is 331,000 times heavier than the earth, the centre of gravity of the two bodies is 331,000 times nearer to the sun's centre than it is to the centre of the earth. Now it can be shown that revolving bodies go round their common centre of gravity, hence the earth revolves round the centre of gravity of itself and the sun and not around the sun; but the sun's mass is so much greater than the earth's mass that their common centre of gravity is inside the former, hence it is usual to speak of the earth as revolving round the sun. Similar reasoning applies, of course, to the motion of the other planets round the sun, and also of the satellites round their respective planets.

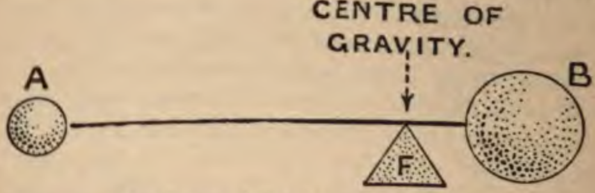


Fig. 25. The Centre of Gravity or Centre of Revolution.

It is interesting to note that if all the members of our system, except the sun, were put in one pan of a balance they would only weigh about $\frac{1}{750}$ as much as our luminary. From this fact it is easy to see that the reason why the earth and all the planets revolve round the sun as the centre of motion is that it has a mass so much greater.

The **laws of planetary motion** were enunciated by Kepler. He was born in 1571 at Würtemberg and was a contemporary of Galileo.

His celebrated laws of planetary motion are:—

(1.) The orbit of each planet is an ellipse, the sun being at one of the foci of each ellipse.

(2.) The line joining the centre of a planet with the centre of the sun, sweeps over equal areas in equal times (Fig. 26).

(3.) The square of the time of revolution of each planet is proportional to the cube of its mean distance from the sun.

These laws apply equally well to the orbits of satellites round their planets, if we substitute the words, 'satellite' for 'planet,' and 'planet' for 'sun.'

From the first law it is manifest that all planets are further from the sun at one end of the major axis of the orbit than when it is at the other end. When a planet is nearest the sun it is said to be in perihelion, and when farthest away it is in aphelion.

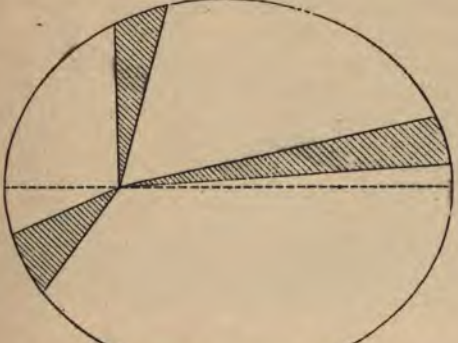


Fig. 26. If the ellipse represent the orbit of a planet, the shaded portions represent the equal areas referred to in the text.

From the second law it is seen that the nearer a planet is to the sun the faster it moves in its orbit.

The third law gives precisely the relation that exists between the motion and distance of a planet.

It has been noted that the interval of time that elapses between two successive appearances of a star above any particular point on the earth is a sidereal year. Similarly, the **sidereal period** of any planet is the time of its revolution around the sun, from a star to the same star again, as seen from the sun. Thus if the sun, a planet and a star are in an exact line at some particular time, the interval that elapses between this time and that of their coming in the same line again is the sidereal period. We really see, however, the movements of the planets from a different point of view than from the sun, and therefore they appear more complicated. Each of the planets, when observed over comparatively long intervals of time with reference to the stars, appear to move forward, stop, go back a little, stop, and move forward again. This, however, is only an apparent motion caused by the different rates of movements of the planets in their respective orbits as seen from the earth in motion; we thus get an apparent period, viz., the time taken by a planet to return to the same position with regard to the sun and earth. This is called the **synodic period** of a planet.

The two planets which travel round the sun within the orbit of the earth, viz.: Mercury and Venus, are called **Inferior** or **Interior Planets**; those whose orbits lie beyond that of the earth, viz.: Mars, the Asteroids, Jupiter, Saturn, Uranus, and Neptune, are called **Superior** or **Exterior Planets.** When an inferior planet is between the earth and the sun, and has the same celestial longitude as our luminary, the planet comes on the meridian at the same time as the sun, and is said to be in **inferior conjunction** with it. When the planet is on the opposite side of the sun, and the two bodies come on the meridian together, it is said to be in **superior conjunction.** A superior planet similarly situated with respect to the sun and earth is merely said to be in **conjunction,** but when the earth is between it and the sun, and the celestial longitude of the two bodies differs by 180°, the planet comes on the meridian at midnight and is said to be in **opposition.** It will be seen from the accompanying illustration (Fig. 27) that an inferior planet can only appear at a certain distance on either side of the sun and apparently oscillates like a pendulum from one side of it to the other, sometimes moving in one direction, sometimes in another. At superior conjunction the planet will appear to move from right to left or **direct**, when it is at inferior conjunction its motion appears from left to right or **retrograde**. The angle between the two lines joining the centres of a planet and the sun to that of the earth is called the **elongation** of the planet from the sun, the greatest **eastern and western elongations** being, in the cases of Venus and Mercury, 47 degrees and 29 degrees respectively.

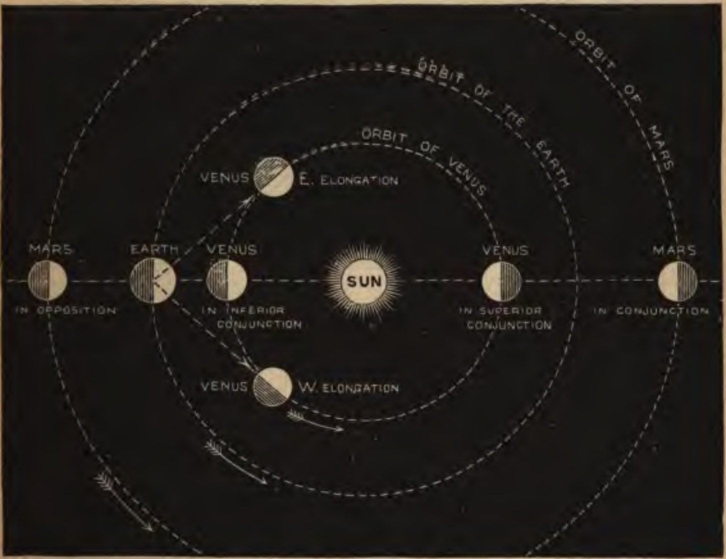


Fig. 27. Planetary Aspects.

The elongation of a superior planet may have any value up to 180°, and, as in the case of an inferior planet, is east or west according to whether it is on the east or west side of the sun.

Quadrature occurs when the celestial longitude of such a planet differs 90° from that of the sun. The planet then passes the meridian about six o'clock in the morning or evening.

Mercury is the nearest planet to the sun. Its mean distance is 36,000,000 miles, but because of the great eccentricity of its orbit the actual distance ranges from 28,500,000, to 43,500,000. The sidereal period of the planet is nearly 88 days and the synodic period—that is, the interval of time between two nearest apparent approaches to the sun as seen from the earth—is 116 days. Its diameter is about 3000 miles, it weighs about $\frac{1}{8}$th as much as the earth, and is about 12 times as heavy as a globe of water would be of exactly the same size. Both the planets between the earth and the sun, *i.e.*, Mercury and Venus, go

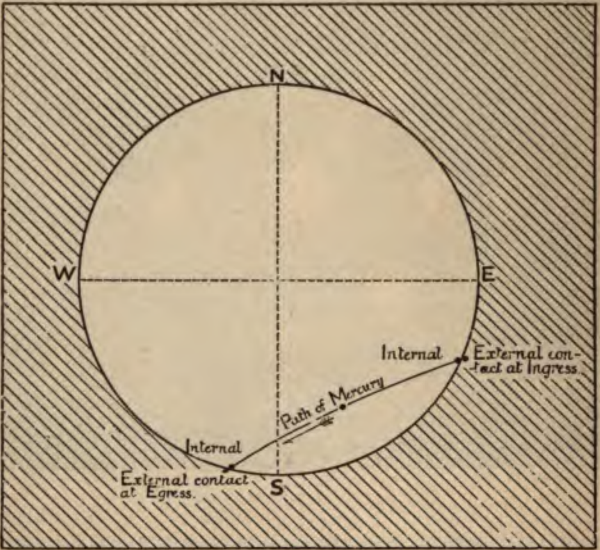


Fig. 28. A transit of Mercury as it may be seen in the latitude of London on May 9th, 1891.

through the same changes as the moon. Sometimes Mercury comes directly between the earth and the sun, and may be seen by means of a telescope to cross his disc as a small black spot. This is called a transit of Mercury and occurs at certain definite intervals of time (Fig. 28). The time of rotation on its axis is not yet known with any degree of accuracy. In 1889 an astronomer named Schiaparelli published observations which seem to indicate that the planet revolves on its axis in the same time that it takes to go round the sun, viz., 88 days. Previous to this, it was supposed to be about 24 hours.

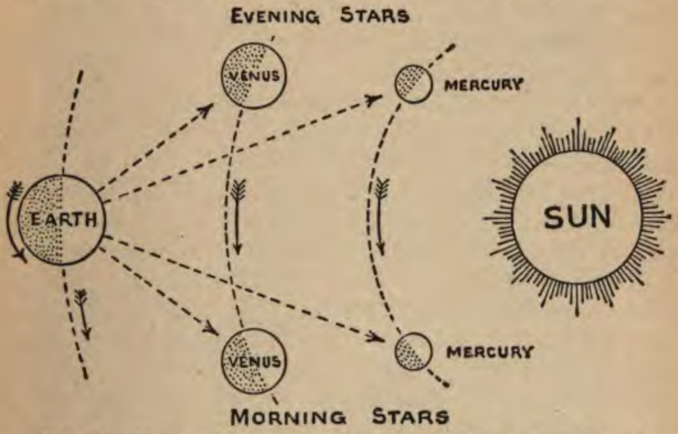


Fig. 29. Venus and Mercury as Morning and Evening 'Stars.'

Venus is, next to the sun and moon, the most brilliant object in the heavens. It goes through the same changes as Mercury and the moon. Accordingly it sometimes rises just before the sun as a 'morning' star, or sets just after the sun, when it is said to be an 'evening' star. The cause of these different appearances is shown in Fig. 29. Occasionally the planet passes between the sun and the earth, and is visible as a black spot upon the sun's disc. This is a transit of Venus, and occurs at alternate intervals of 120 and 8 years. The sidereal period is 225 days and the synodic period 584 days. The mean distance of Venus from the sun is 67,200,000 miles, and, owing to the small eccentricity of its orbit, the greatest and least distances only differ from this by about 470,000 miles. Its mass is about $\frac{4}{5}$th that of the earth, its diameter is about 7,700 miles, and it would weigh about five times as much as an equal globe of water. The period of rotation has been stated as nearly 24 hours, but Schiaparelli has brought forward evidence to prove it to be equal to its revolution period, that is, 225 days.

A dense atmosphere surrounds the planet and evidence of water-vapour is found in it.

The **Earth**, the next planet in order of distance from the sun, is described elsewhere.

Mars is the first planet outside the orbit of the earth. Its mean distance from the sun is 141,500,000 miles, and, because of the great eccentricity of its orbit, this distance varies by about 13,000,000 miles. The sidereal period is 687 days, and synodic period 780 days. The planet's diameter is 4200 miles, and its mass, or the quantity of matter it contains, is about $\frac{1}{10}$th that of the earth. The time of rotation is 24 hours 37 minutes, 23 seconds, as determined by observations of markings upon the surface. Deposits of ice and snow are seen at each pole of this planet; these deposits alternately diminish and increase as the north and south poles approach the summer and winter solstices. This is analagous to what occurs on the earth, and demonstrates the presence of considerable quantities of water-vapour in the Martian atmosphere. The analogy with the earth is strengthened by some observations of direct lines of water, known as canals, running across the land surface of the planet in all directions. Two small satellites were discovered in 1877 to revolve round the planet; they can only be observed, however, with very powerful telescopes.

A group of **minor planets or 'asteroids,'** has been found to revolve around the sun between the orbits of Mars and Jupiter Up to the present time (October, 1891) 318 of these small and extremely faint bodies have been discovered. It was thought for a long time that an unknown planet moved in the space between the orbits of Mars and Jupiter. A search for this planet led to the discovery of the first 'asteroid' in 1801. The largest of these bodies cannot be more than 300 miles in diameter, and some are probably no more than 10 miles, whilst the whole lot now known have only a bulk about $\frac{1}{4000}$ that of the earth. The view is held that these minor planets

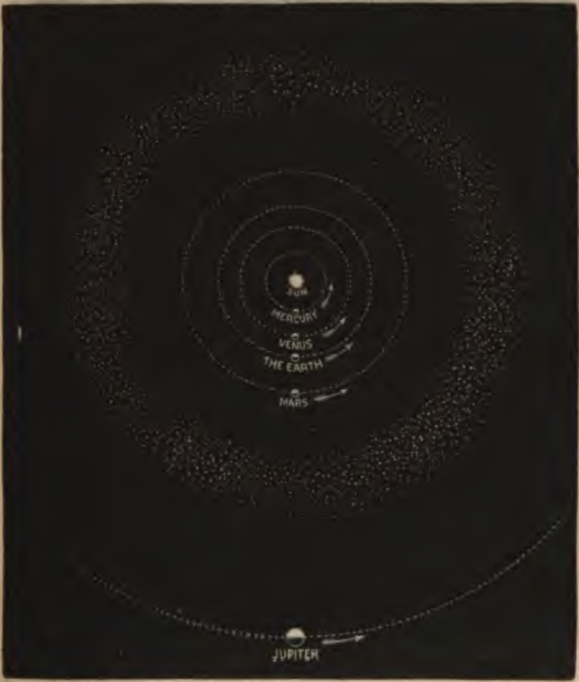


Fig. 30. Portions of the Orbits of the Planets inside the Orbit of Jupiter.

were formed by a series of explosions and breakings up of a large planet.

Portions of the orbits of the planets that revolve around the sun inside the orbit of Jupiter are shown in Fig. 30.

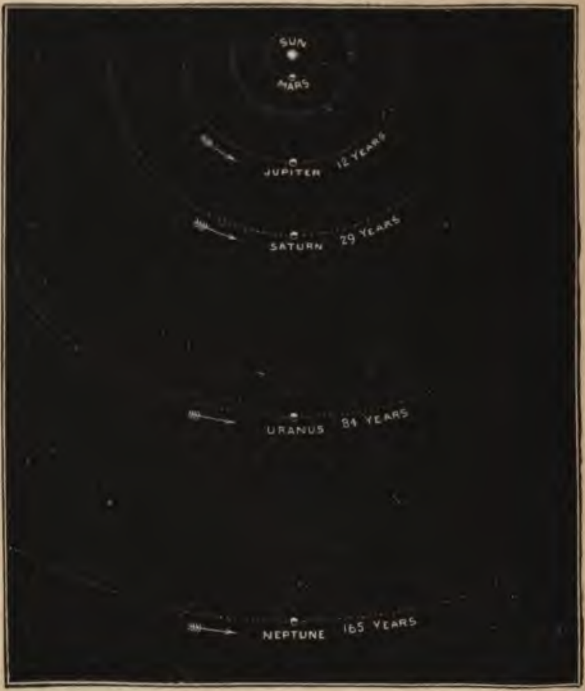


Fig. 31. Portions of Planetary Orbits outside that of Jupiter.

Jupiter, the largest of all the planets, is nearly as bright as Venus at her best. His mean distance from the sun is 483,000,000 miles, with a variation of about 21,000,000 miles each way, because of the eccentricity of the orbit. The sidereal period is 11·86 years, and the synodic period is 399 days. The equatorial diameter is 88,200 miles, the polar diameter 83,000 miles; the mean of these is 85,600 miles, or nearly eleven times more than the diameter of the earth. The mass of the planet is 316 times that of the earth, but the materials of which it is made only weigh about $\frac{1}{4}$ as much as those which make up the earth. He rotates on an axis in about 10 hours. Observations of the motion of great belts of cloud indicate that this giant planet has not yet cooled right down to the temperature of the earth, but emits a certain amount of light and heat of its own. Four satellites, having diameters from 2,000 to 3,600 miles, revolve round the planet as their primary.

The orbits of the planets that revolve around the sun outside the orbit of Jupiter are shown in fig. 31.

Saturn is the remotest of the planets known to ancient astronomers. Its mean distance from the sun is 886,000,000 miles, with a variation of nearly 50,000,000, on account of the eccentricity of its orbit. The sidereal period is 29½ years, and the synodic period 378 days. This planet differs from all the rest in being surrounded by a system of rings, in addition to eight satellites. The mean diameter is nearly 71,000 miles, and therefore the volume of the planet is nearly 740 times that of the earth; the mass, however, is only 95 times that of the earth, hence the materials of which it is made up are only $\frac{1}{8}$ as dense as those forming the earth. Cloud belts running parallel to the equator are seen on this planet as on Jupiter, but they are not so well marked nor so variable in character. The time of rotation on its axis is about 10 hours 14 min. Although the outer ring surrounding Saturn is 168,000 miles in diameter, its thickness is not more than 100 miles. There is no doubt, however, that the rings are not of uniform thickness. It has been proved beyond all doubt that this ring system could not exist if it were a solid mass, and the theory is now universally accepted that it is made up of a swarm of separate particles—a ring of meteorites—revolving round the planet.

Uranus was the first planet discovered in modern times. Sir William Herschel in 1781 observed an object in the field of his telescope which he thought was a comet, and announced his discovery as such. Further investigations proved that the new body was another planet. The mean distance of Uranus from the sun is nearly 1,800,000,000 miles. Its periodic time is 84 years, and synodic period 369 days 8 hours. The diameter of the planet is 32,000 miles, and about 66 earths would be required to make up its volume; the mass is, however, only 14·6 times that of the earth, hence it is, bulk for bulk, about $\frac{1}{5}$ as heavy as the earth, that is, about the density of water. Uranus appears as a faint sea green disc in a telescope, and from some markings on its surface a time of rotation has been given to it, but with no degree of accuracy Four satellites revolve round Uranus as a primary.

Neptune was known to be in existence before it was observed. Uranus does not move exactly in the path that it would if nothing disturbed its motion. It was suggested that the disturbing body was another planet outside Uranus. Calculations were made on this assumption in 1844-45 by Professor J. C. Adams in England and Le Verrier in France, and the position which ought to be occupied by the unknown planet predicted. Directed by Le Verrier, an observer named Dr. Galle pointed his telescope to a certain position in the sky, and in accordance with the prediction the unknown planet was found close to its calculated position. Neptune's mean distance from the sun is 2,800,000,000 miles, with a variation of 50,000,000, owing to the eccentricity of the orbit. The periodic time of the planet is 164 years, and the synodic period 367½ days. Its diameter is about 35,500 miles, its volume a little more than 90 times that of the earth, and its mass about 18 times. Thus the density of the planet is $\frac{18}{90}$, or $\frac{1}{5}$ that of the earth, or about the density of water. Neptune has one known satellite, about the same size as our own moon. It is, however, very probable that more satellites accompany this planet, but are too small to be visible at the great distance of the earth. There is also every reason to believe that another planet will be found beyond the orbit of Neptune. The comparative diameters of the planets are shown in Fig. 32.

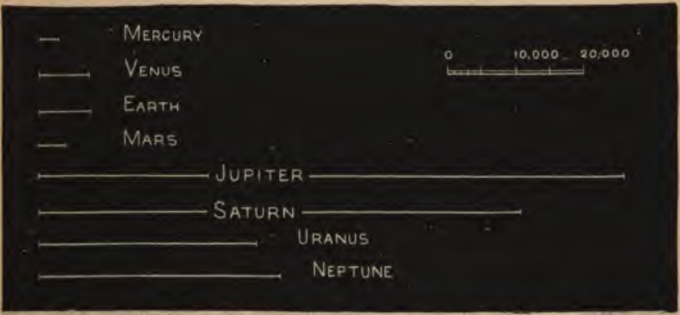


Fig. 32. Comparative diameters of the Planets.

From the foregoing it will be seen that the planets are naturally divided into two groups. Our earth is one of four comparatively small planets, whilst Jupiter, Saturn, Uranus and Neptune are four much larger bodies. The group similar to the earth are called **terrestrial planets**; the members of the other group are called **major planets.** There are other considerations besides size which point to such a division of the members of our system. The terrestrial planets have high densities, are covered with water and air, and probably like the earth in physical constitution, have a comparatively small number of satellites and a slow velocity of rotation on their axes. The major planets are much less dense, their density not differing considerably from that of water; they have a much greater number of satellites revolving round them, and rotate more rapidly on their axes, hence their days are shorter than those of the terrestrial planets. It is also very probable that the major planets are at a high temperature, and emit a certain amount of light of their own.

Many **Comets and Meteorites** revolve round the sun, but before entering into an explanation of their constitution it is necessary to premise a little.

There is evidence to show that space is filled with small fragments of matter. As the earth revolves around the sun many of these fragments enter our atmosphere, and the friction of the air upon the rushing particles develops enough heat to render them luminous and give the appearance of a meteor. These meteors are commonly called 'falling stars,' although they are totally different from the fixed stars seen every night in the sky. Sometimes the heat developed is not sufficient to entirely melt up and vaporise the whole fragment, and a portion falls to the ground as a *meteorite*. Analyses of meteorites show that they are made up of the same elements as are found on our earth. Now, it is a consequence of gravitation that the meteorites in space should form into groups. Such groups have been drawn into our system from outside space by the attraction of one of the major planets and the sun, and they revolve round the sun in a definite path. More than one hundred distinct swarms of meteors are now recognised as belonging to our system; many of these swarms are small, but some are very large and extended. Our earth passes through the thickest part of one swarm on the 13th of November once in thirty-three years, and therefore on this date an unusually large number of shooting stars are seen to fall. The last display was in 1866, hence the next will be in 1899. Calculations show that five comets travel around the sun in exactly the same path as five of the largest meteor-swarms, and there seems absolutely no doubt that these comets represent but the thickest part of a swarm of fragmentary particles of matter revolving around the sun. In fact, some recent investigations by Professor Lockyer prove that all comets are but swarms of meteorites. When a swarm enters our system its temperature is comparatively low, but as it is drawn towards and approaches the sun the meteorites meet more often. The result of each collision is a development of heat, hence comets get hotter as they approach the sun and cooler as they recede from it. The tail of a comet is composed of the vapours driven off from the meteorites as their temperature is increased by collision; thus the tail grows as the sun is approached, and, as a matter of fact, when comets are seen at a great distance from the sun they have no tails but simply appear as faint globular patches of light. The paths traversed by comets are much more elongated ellipses than those in which the planets revolve round the sun; thus they are ofttimes at immense distances away when at their greatest distance, and comparatively near to the sun when at their shortest distance.

GENERAL SUMMARY OF CHAPTER V.

The Solar System is composed of:—

The Sun, the central body.

Eight Large Planets as follows, in the order of distance from the Sun.

Mercury.
Venus.
Earth.
Mars.
Jupiter.
Saturn.
Uranus.
Neptune.

A Ring of small Planets or asteriods revolving between the orbits of Mars and Jupiter (about 299 of these bodies are now known).

A number of Satellites of the planets, 20 being now known.

A Number of Comets and meteoritic bodies revolving in very eccentric orbits.

All the planets revolve round the sun in nearly circular orbits and the direction of motion viewed from above the system is **direct** or opposite to that of the hands of a watch. Many of the comets, however, move in an opposite direction, and are said to have **retrograde** motion.

Principal Elements of the Solar System.

	Eccentricity of orbit	Mean Distance from the sun in millions of miles	Sidereal Period in mean solar days	Sidereal Period in years	Synodic Period in days
Sun	......	......	......	......	......
Mercury	20·56	36	87·9	0·24	116
Venus	0·68	67	224·7	0·62	584
The Earth	1·68	93	365·2	1·00	......
Mars	9·33	141	686·9	1·88	780
Jupiter	4·81	483	4332·6	11·86	399
Saturn	5·61	886	10759·2	29·46	378
Uranus.	4·67	1782	30686·8	84·02	370
Neptune	0·87	2792	60181·1	164·78	367½

	Inclination of Orbit to Plane of Ecliptic			Mean Diameter in miles	Volume Earth = 1	Mass Earth = 1
Sun	......			866,000	1,300,000	331,000
Mercury	7°	0′	8″	3000	0·05	0·12 ?
Venus	3	23	35	7700	0·92	0·78
The Earth	0	0	0	7918	1·00	1·00
Mars	1	51	2	4230	0·15	·10
Jupiter	1	18	41	85,600	1309	316·0
Saturn	2	29	40	71,000	721	94·9
Uranus	0	46	20	32,000	65	14·7
Neptune	1	47	2	34,800	85	17·1

	Relative Density Earth = 1	Relative Density Water = 1	Sidereal day or time of Axial Rotation	Number of Satellites
Sun	0·25	1·39	25 days	...
Mercury	2·23	12·44	24 hours or 88 days	0
Venus	0·86	4·85	24 hours or 225 days	0
The Earth	1·00	5·58	23 ,, 56 mins.	1
Mars	0·72	4·01	24 ,, 37 ,,	2
Jupiter	0·24	1·33	9 ,, 55 ,,	4
Saturn	0·13	0·72	10 ,, 14 ,,	8 & 3 rings
Uranus	0·22	1·22	Unknown	4
Neptune	0·20	1·11	,,	1

The Eccentricity of a planet's orbit is the ratio which the distance of the centre of the orbit from the sun bears to the semi-axis major.

The Sidereal Period of a planet is the time of its revolution around the sun, from a star to the same star again, as seen from the sun.

Synodic Period.—When a planet crosses the meridian the same time as the sun the two are said to be in conjunction; when a planet comes on the meridian at midnight, that is, twelve hours after the sun, the two are said to be in opposition. The synodic period of a planet is the time between two successive conjunctions, or oppositions, of the planet with the sun, as seen from the earth.

Inclination.—If the orbit of each planet be represented by an oval wire loop, the above numbers representing the inclination of the orbit to the plane of the ecliptic indicate the amount that each loop, respectively, is inclined to that representing the earth's orbit.

Mean Diameter.—All the planets are most probably spheroidal in form, that is, the polar diameter is shorter than an equatorial diameter. The amount of oblateness in known with some degree of accuracy in the cases of the Earth, Mars, Jupiter and Saturn, but not for the remainder. The above figures represent the average of the two diameters.

Volume.—This is determined from the diameters by ordinary rules of mensuration.

The Mass of any body is the quantity of matter it contains, and in the above case is the mass of the members of our system compared with the mass of the earth.

The Density of a planet compared with the earth is determined by dividing its mass by its volume. Thus the mass of the sun is 331,000 times greater than that of the earth, and its volume is 1,300,000 times greater than the earth's volume, therefore, density of sun compared with that of the earth = $\frac{331000}{1300000}$ = 0·25 (about).

Sidereal Day.—As in the case of the earth, the sidereal day is the time intervening between two successive transits of the same star, over any particular point on a planet and is, therefore, the time of rotation on its axis.

Inferior and Superior Planets, or interior and exterior planets, are those whose orbits are respectively within or outside of the orbit of the earth.

The Terrestrial Planets are characterised by their:—

Small size; mean diameter about 5700 miles.

High density; mean = 6·72.

Small number of satellites. Of the twenty known satellites only three belong to the terrestrial planets.

Slow velocity of rotation. The day of the terrestrial planets is about 24 hours long.

The Major Planets are characterised by their:—

Great size; mean diameter about 56,000 miles.

Low density, mean = 1·09.

Large Number of Satellites.

High Velocity of Rotation. The day of the major planets is only about 10 hours long.

CHAPTER VI.

THE MOON.

Everyone knows that the disc of the moon is variegated by irregular dark patches which have been imagined to have some resemblance to a human face. These dark and apparently smooth portions of the lunar disc were considered by early telescopic observers to be seas, and the brighter portions were thought to be continents. As the telescope was improved, however, the supposed resemblance between the earth and the moon was shown to be more fanciful than real, and we now know that the earlier astronomers' seas are almost as broken up as any other region.

It often happens that the moon passes right in front of a star, and the star is then said to be occulted, the occurrence being called an **occultation.** Observations show that a star does not fade slowly out of sight, nor does it undergo any apparent displacement, as it would do if an atmosphere surrounded our satellite, but disappears suddenly behind the moon without suffering the least displacement or fading. Such observations conclusively prove that the moon has no appreciable atmosphere, hence no water or other volatile fluid can exist there, and it must be as lifeless as an arid rock. We know the sun to be at a high temperature and self luminous; the surface of the earth is cool, but the temperature increases as we go down, showing that a high temperature exists in the interior of our globe; our satellite, however, seems to be a cold dead body. There is little doubt that the moon, earth and sun at one time were all at the same temperature. The sun as it cooled—for it was once much hotter than it is now—threw off the earth, and the earth similarly threw off the moon. The three bodies are illustrations of the ordinary

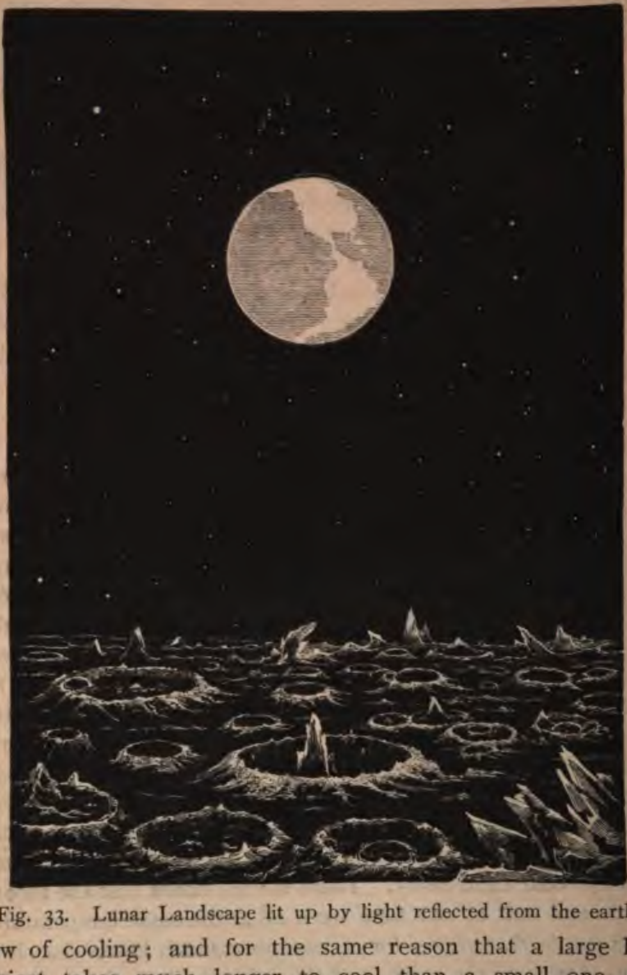


Fig. 33. Lunar Landscape lit up by light reflected from the earth.

law of cooling; and for the same reason that a large hot object takes much longer to cool than a small one, we find the temperature of that enormous mass, the sun, considerably higher than that of the earth, and the temperature of the earth much higher than that of its smaller companion the moon. The lunar surface presents exactly the appearance of an old world; it is covered with craters of extinct volcanoes, compared with which the volcanoes on our earth are pigmies; and this is exactly the appearance that would follow on the shrinking of a hot body by cooling (Fig. 33). An apple gets wrinkled when kept for a time, the reason being that the interior which once filled out the skin has been dried up. As people get old they lose the fat and muscle that once filled out their skin and the latter becomes wrinkled. Both these cases show how a shrinkage of the interior causes a wrinkling of the crust; and the analogy may be applied to the moon to account for its appearance.

The diameter of the moon is 2,160 miles or about $\frac{3}{11}$ that of the earth, hence it would take fifty moons to form a single body the same size as the earth.

Everyone knows that a ball of lead weighs more than an iron ball of the same size. Similarly, it has been found that the earth is 80 times heavier than the moon, although it is only 50 times larger; hence the materials which make up the moon must be lighter, bulk for bulk, than those forming our globe and in the proportion of 50 : 80, that is, the relative density or specific gravity of the moon compared with the earth is $\frac{5}{8}$. At the end of the last chapter the earth's specific gravity is given as 5·58, hence the specific gravity of the moon is $\frac{5}{8}$ of 5·58 = 3·6—that is, the moon weighs about $3\frac{1}{2}$ times more than it would weigh if it were wholly composed of water.

It can be proved in a similar manner to that illustrated by the sun, that the moon obeys Kepler's laws of motion, and that her path is an ellipse of which the earth occupies one of the foci.

It follows from the elliptical form of the moon's orbit that the distance of our satellite varies; when it is nearest the earth it is said to be in **perigee** and when furthest away to be in **apogee**. By measuring the greatest and least diameter of the moon at perigee and apogee respectively, the eccentricity of the orbit has been found to be $\frac{1}{20}$, that is to say, if the distance from the centre of the ellipse to an extremity of the major axis be represented by 20 inches, the earth's position would be one inch out of the centre. In consequence of this large eccentricity (the eccentricity of the earth's orbit is only $\frac{1}{60}$) the distance of the moon from the earth varies considerably. It may get as near as 221,000 miles or so far away as 259,600 miles; the average distance, however, is about 240,000 miles. The average distance of the sun from the earth is 93,000,000 miles, therefore the moon is only about $\frac{1}{400}$ the distance of the sun from the earth.

The orbit of the moon around the earth does not lie in the plane of the ecliptic but is inclined to it at an angle which varies between 5° 0′ and 5° 17′, hence the apparent path described by the moon among the stars is not the same as that described by the sun, viz., the ecliptic, but is inclined to it at an angle of about 5°.

A circumstance that must have struck the most casual observer is that the moon always presents the same face to the earth. The explanation of this fact is that the moon rotates on its axis in the same time that it takes to perform a revolution round the earth. Let us conceive ourselves to be looking down upon the earth and moon from somewhere in space (Fig. 34). The moon presents the hemisphere BAD to the earth; let it move through 90°, then, if it did not rotate, the hemisphere ABC would be presented to the earth; but we know from observation that the same part of the lunar surface is seen—hence, while the moon moves 90° in her orbit she rotates 90° on her axis, and therefore while she completes a revolution around the earth, that is, describes 360°, she also completes a rotation on her axis. The period of revolution with respect to a star—that is, the time that elapses between two successive appearances of the same star over some particular point in the moon—is 27 days, 7 hours, 43 mins., 11 secs., and this is, therefore, also the time taken by the moon to perform one axial rotation. It would thus appear that it is impossible for us to see more than one half of the lunar surface; but, as a matter of fact, we see more than this. If a crater be observed exactly on the edge of the moon at a certain time, a series of observations would show that sometimes it appeared

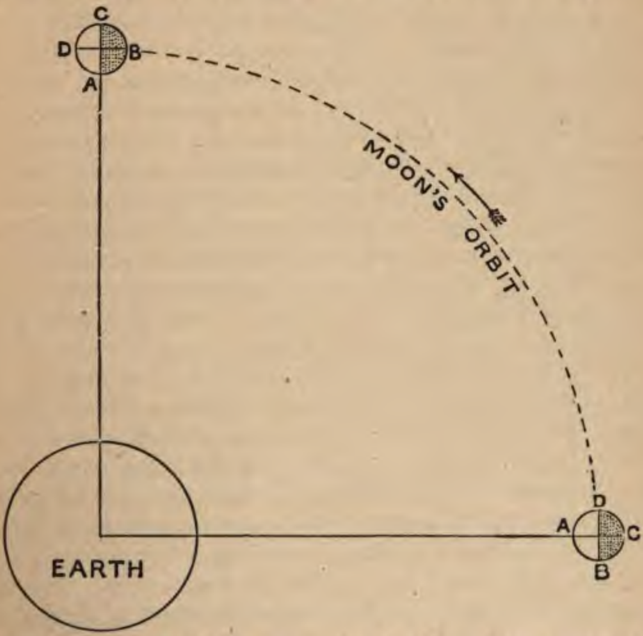


Fig. 34. Illustration of the reason why the Moon always presents the same face to the Earth.

right on the edge of the moon and sometimes was removed from it; in fact, the crater would be seen periodically to approach to and recede from the border of the disc. These periodical oscillations whereby we see slightly more than one half of the lunar surface are called **librations**. The following is the explanation of the appearance. The second law of planetary motion is that the line joining a planet to the sun sweeps over equal areas in equal times; this also applies to the motion of the moon around the earth, and hence the line joining the moon to the earth sweeps over equal areas in equal times. The consequence of this law is that the moon moves fastest when she is nearest the earth (perigee) and slowest when she is farthest away (apogee). To sum up, we have the fact that although the rotation of the moon on its axis is perfectly uniform, the revolution round the earth is variable. If both motions were uniform, and took place in equal times, we could not possibly—from this cause—see more than one definitely defined lunar hemisphere; but, because they are not, a periodical oscillation appears to take place in lunar longitude, completing all its motion in the time of the moon's revolution around the earth. In consequence of this **libration in longitude**, we are able to see 265 miles more of the moon's surface, in an east and west direction, than we should be able to see if both rotation and revolution were uniform.

We have noted that the moon's orbit is inclined about 5° to the plane of the ecliptic. The axis of rotation is only 1° 30′ out of the perpendicular to this plane, thus the plane of the moon's equator almost coincides with the plane of its orbit. In consequence of the double inclination of 6½° to the plane of the ecliptic, we see a portion of the southern pole of the moon when she is above or north of the ecliptic, and a portion of the northern pole when she is below or south of the ecliptic; whereas, if the moon revolved around the earth in the ecliptic plane, and, having her axis perpendicular to that plane or at a constant angle to it, we should always see the same amount of lunar surface in a north and south direction, and a point on the top or bottom edge of the moon would always be exactly at the top and bottom.

The reason of this is easily understood from analogy with the earth. An observer on the sun would sometimes see the earth's north pole and sometimes the south pole, the amount visible varying with the position of the earth in its orbit. This alternate showing of the moon's north and south poles is called the **libration in latitude,** and enables us to see, both north and south, 225½ miles more of the moon's surface than would otherwise be visible. We must add that since libration in longitude and in latitude arise from the motion of the moon itself, they are both independent of the position of the observer on the earth.

There is yet another of these librations of the visible hemisphere of our satellite; but, unlike the two previous ones, which have a period of a month, this has a daily period, and hence is termed the **diurnal libration.** Consider an observer on the earth's surface, and the moon to be just on his meridian; he sees a certain hemisphere; as the earth rotates the observer will be caused to view the moon from a different point, and will see at different times during the night portions of the moon's disc beyond the border visible when it was on the meridian. Similar *parallactic* effects may be produced by travelling North or South. By means of the three librations we can see $\frac{58}{100}$ of the moon's surface, that is, if the whole surface of the moon be represented by 100, 58 parts may be seen by means of libration, leaving 42 parts always unseen and unknown.

We always see the sun as a complete circular disc; the moon, however, goes through a series of periodically recurring changes. From the thin crescent, seen shortly after new moon, the bright portion of the lunar surface increases in size night by night until half of the disc is seen, then full moon occurs, then half moon again, and finally the crescent thins down to invisibility. These changing appearances are called the **phases of the moon.**

The light we receive from the planets is reflected sunlight and not due to an appreciable extent to any self luminosity. The moon also shines by reflected sunlight. When the rays of the sun fall upon any opaque body they illuminate it.

We sometimes see the walls of houses glaringly bright, but we know that it is only sunlight second-hand. It is the same with the moon; and we have now to explain why, although the sun is always shining on our satellite, we do not always see a fully illumined circular disc.

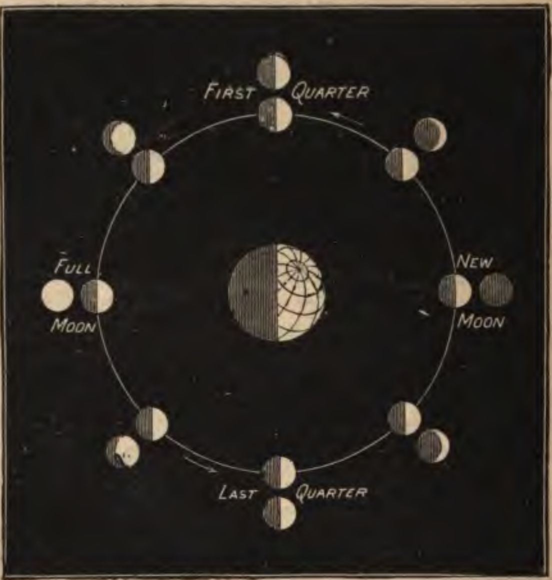


Fig. 35. Phases of the Moon. The Sun is not represented, because its distance from the Earth is about 190 times the diameter of the Moon's orbit.

It has been noted before that the average distance of the moon from the earth is 240,000 miles. The distance of the sun, however, is so great—being nearly 400 times this distance of the moon's—that rays coming from it and falling upon the earth and moon may all be considered parallel. Let the moon occupy the position opposite the sun as shown on the left of Fig. 35; then, since it is generally above or below the ecliptic, some of the sun's rays passing above or below the earth will strike full upon its surface, and the inhabitants on the dark side of the earth, that is, on the side of the earth turned away from the sun, will see a 'full moon.' When the moon occupies this position with respect to the sun and earth, the rotation of our globe causes it to cross the meridian about midnight. At such times the sun and moon are said to be in opposition.

The times of rising, passing the meridian, and setting get later each night, and about a week after full moon it will put on the appearance of a half moon, which may cross the meridian about 6 a.m., as the sun is rising. At such times the sun and the moon appear together in the sky, and if it were not for the glare of the sun's rays in our atmosphere we should see the moon until midday; but we know that as the run rises in the sky it extinguishes the feeble rays of the moon. From the appearance of half moon more and more of its surface becomes obscured, the visible portion becomes crescent shaped, the interval between its passage across the meridian and the sun's passage is lessened, and our satellite is only seen in the morning shortly before sunrise.

About a fortnight after full moon nothing is seen of it, and the reason is manifestly because, as is shown in the accompanying figure, its dark side is turned towards the earth. A time comes when the sun and moon are in conjunction, that is, they both cross the meridian at the same time, the moon perhaps a few degrees above or below the sun, which is in the ecliptic, but on the same celestial meridian. The moon is said to be new when it is in conjunction with the sun, but it will be understood that at this time it cannot be seen at all. If, about four days after new moon, we watch the sun set in the west, a narrow crescent of light will be observed to set a few hours after it, the horns or cusps of the crescent being turned away and equi-distant from the sun. This crescent will cross the meridian a few hours after the sun. Of course, strictly speaking, a crescent is formed as soon as the moon passes conjunction, but twilight renders it invisible until about four days after new moon. The crescent grows day by day, and seven days after new moon the appearance of half moon will again occur; this half moon will cross the meridian six hours after the sun, that is, at 6 p.m. The bright portion of the lunar surface will go on increasing; its times of rising, meridian passage and setting will get later; and on the fourteenth or fifteenth day after new moon the whole disc is again lit up and another full moon occurs, which passes the meridian at midnight.

To sum up the various phases of the moon, we have:—

An invisible new moon at conjunction.

Crescent-shaped moon, between new moon and half moon, that is, between conjunction and quadrature.

Half moon occurs about seven days after new moon, and our satellite is said to be in the first quarter or at quadrature.

Gibbous moon, between the first quarter and full moon, that is, between quadrature and opposition.

Full moon, about a fortnight after new moon, when it is at opposition.

After the full our satellite again becomes gibbous, then passes half moon or the last quarter, then diminishes to a thin crescent and finally returns to new moon to commence afresh the cycle.

In order to clearly understand why the moon should go through all these changes, although the sun lights up a whole hemisphere, the student is recommended to get a ball of some kind and paint half of it white. If this ball be carried around the student with its painted face always turned in a fixed direction, it will be observed that sometimes the full painted surface is seen sometimes half, and sometimes none at all. This is exactly analagous to what happens in the case of the moon; the rays of the sun fall upon our satellite and always illuminate the half facing it. The bright portion is always on the side near the sun, but although the rest is not bright it still exists. We do not, however, always see this fully illumined disc, but various portions of it depending upon the relative position of the earth and moon.

If the number of days be noted from full moon to full moon it will be found to be nearly 29½ days; this constitutes a lunar month or a lunation, and is the time of a **synodic revolution of the moon.**

Our satellite describes a great circle in the heavens, in a plane inclined about 5° to the ecliptic. We may therefore note the interval of time between two consecutive passings of the moon in front of a particular star; this gives us the time of a **sidereal revolution of the moon,** that is, about 27⅓ days.

It will be noted that a synodic revolution of the moon is about two days longer than a sidereal revolution, that is, a revolution of the moon with respect to the sun is two days longer than one with respect to the stars. The explanation of this difference is found in the following. We have shown that the movement of the earth in its orbit from west to east causes the sun to appear to travel eastward right round the heavens in a year. Consider then the sun, moon and some star on the meridian; in 27⅓ days the moon will appear exactly in front of the same star, but the sun has moved on a little among the stars during that time, and it takes the moon two days to catch up to him again; the two bodies are then on the same meridian as some other star and the cycle begins afresh.

One or two facts follow upon the varying changes of the moon. In the first place, the two horns of the moon seen before the first and after the last quarter must always be equidistant from the sun, and turned away from it. No matter where the moon is in her orbit, the line of greatest width must point to the sun.

When the moon is near conjunction and her crescent is small, a faint ashy light is seen to illuminate the whole hemisphere, the bright crescent appearing part of a somewhat larger disc than the dark portion. This appearance is commonly known as 'the old moon in the young moon's arms.' The cause is manifest from an inspection of the accompanying figure. It will be seen that when the moon is near conjunction the light of the sun is reflected from the earth and illuminates its whole hemisphere. Indeed, an observer on the moon would see the earth go through exactly the same phases as we do the moon, but in a reversed order, so that when it is new moon with us it is *full earth*, so to speak, to an observer on this side of the moon. The bright crescent appears larger than the other portion of the moon because of the optical effect called **irradiation,** that is, a white or bright body always appears larger than a dark one of the same size.

The amount of light given to the earth by the moon is very small compared with that of the sun, careful determinations showing that the sun gives us about 620,000 times as much light as the full moon.

Since the moon reflects the light of the sun it must reflect heat also, and one determination made the amount $\frac{1}{82000}$ of that received from the sun. The temperature of the moon is most probably far below the temperature at which water freezes. As the sun's rays, however, strike on the lunar surface without being modified at all by passing through an atmosphere, the lunar surface must get much hotter, comparatively speaking; and recent determinations indicate that the temperature of the soil of the moon lit up by the sun is about that of the freezing point of water.

Eclipses. It occasionally happens that at the time of full moon part or the whole of its disc becomes obscured. A dark shadow, having a circular outline, first appears on the eastern edge, slowly passes over, sometimes blotting out entirely the light of our satellite, and then leaves at the western edge. Thus the eastern edge becomes first obscured and is the first part to become visible after obscuration. These appearances are called eclipses of the moon. The fact that such eclipses always occur at full moon was early noticed, and the idea that the cause of an eclipse was the moon passing into a shadow cast by the earth suggested itself, and was understood by the earliest observers. We are now in a position to investigate the cause more closely.

If an opaque ball be held in front of any source of light, we know by common experience that it will cast a shadow; this shadow is made up of two portions—one dark central part called the **umbra,** and a less dark part surrounding it called the **penumbra** or part shadow. The sun is a source of light, and our earth is an opaque sphere; hence, since the earth is always in the sun's rays, it is always casting a shadow. This shadow will have the conical form shown in Fig. 36, the black portion indicating the umbra and the outer portion the penumbra. We have before noted that the plane of the earth's revolution around the sun is the plane of the ecliptic, hence a line joining the centres of the earth and sun and the apex of the umbra must lie in that plane. It is evident, therefore, that if the moon moved around the earth in the plane of the ecliptic, it would always pass into the earth's shadow at opposition, that is, at full moon, and we should never see a full moon. But we know that the moon's orbit is inclined a little more than 5° to the ecliptic plane, hence, at opposition, she may be any distance from 0° to 5° either above or below the ecliptic, and therefore any distance from 0° to 5° above or below the apex of the conical shadow cast by the

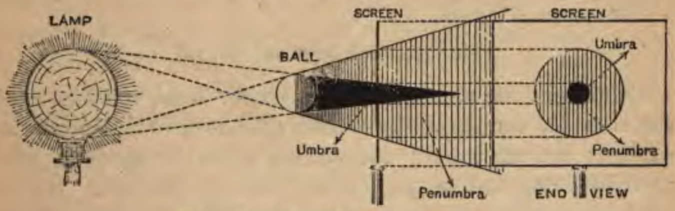
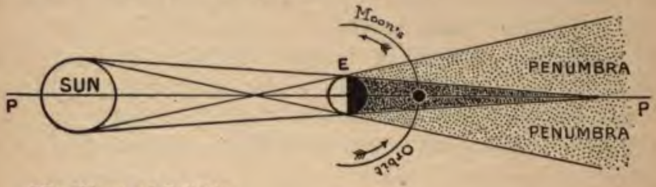


Fig. 36. Structure of a Shadow.

earth. Twice in every month the moon is at a **node**, that is, at one of those points where the plane of its orbit intersects the ecliptic plane, and if it is either 'new' or 'full' at such times an eclipse must occur. When, therefore, the sun, earth, and moon are exactly in the same straight line, the moon, if not beyond the apex of the earth's shadow, will pass through it and be eclipsed (Fig. 37).



PP = Plane of Ecliptic.

Fig. 37. Eclipse of the Moon.

Eclipses of the moon are of two kinds: total, in which case she is totally immersed in the earth's shadow, so that no direct sunlight can reach her; and partial, when the moon is only partially immersed in the earth's shadow. In order that a total eclipse of the moon may happen, our satellite must be at one of the points where its orbit intersects the ecliptic. If she is not exactly at one of these points a partial eclipse may only occur, because then only a portion of the upper or lower limb passes through the earth's shadow. When a total eclipse of the moon occurs, the eastern limb comes in first contact with the penumbra of the earth's shadow. This effect, however, is barely perceptible to the naked eye, and little loss of light is noticed until the umbra is reached, when the eastern edge becomes almost invisible, the circular shadow encroaches slowly upon the bright lunar surface and totally eclipses it for about two hours. After this the shadow is seen to pass off at the western edge of the moon. It is noticed that during a lunar eclipse a coppery-coloured light appears to illuminate the moon. If the earth had no atmosphere surrounding it, this would not happen; the explanation of the phenomenon being that the sun's rays which pass near to the earth are bent or refracted by its atmosphere into the cone which forms the shadow, thus illuminating the lunar surface in the manner already described. It is also possible that a certain amount of real earth-shine adds to the effect. The duration of an eclipse of course depends upon the time taken by the moon to pass through the umbra and penumbra of the earth's shadow, and as a matter of fact a total eclipse of the moon lasts about two hours, and if the partial darkening on each side of the umbra be considered the time may be extended to three or four hours.

Besides the darkening of the full moon, called an eclipse of the moon, the light of the sun is sometimes cut off. A dark shadow meets the western edge of our luminary, passes over its disc, and totally eclipses it, it may be for seven minutes, it may be for a few seconds. This appearance is called an eclipse of the sun, or a solar eclipse.

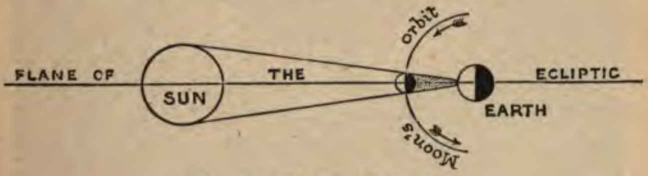


Fig. 38. Eclipse of the Sun.

Lunar eclipses are caused by the earth coming between the sun and moon, and occur at opposition, that is, at full moon. Solar eclipses are caused by the moon coming between the earth and the sun, and occur at conjunction, that is, at new moon. If the moon's orbit coincided with the ecliptic, a solar eclipse would happen every new moon, but as the orbit is inclined about 5° to the ecliptic, the moon sometimes passes above and sometimes below the line joining the centres of the sun and earth, and so her shadow does not touch the earth. A diagrammatic representation of a solar eclipse is shown in Fig. 38

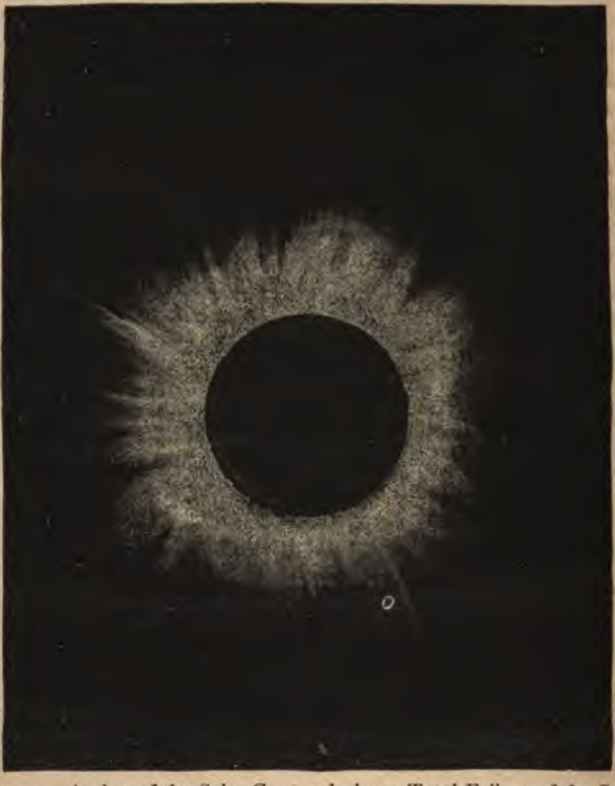


Fig. 39. A view of the Solar Corona during a Total Eclipse of the Sun.

Solar eclipses are of three kinds, total, annular, and partial, and it is evident from an inspection of the accompanying figure, that a total eclipse can only occur when the observer is near the line joining the centres of the sun and moon; indeed the breadth of this space traced upon our globe by the lunar umbra never exceeds 180 miles. An observer situated within this belt sees a dark shadow cross the sun from west to east, eclipsing it totally for a short time. As the sun's light is shut off by the moon's shadow, the stars are seen to come out and a halo or corona appears to surround the lunar disc (Fig. 39). This halo belongs to the sun and is invisible under ordinary circumstances because of the sun's glare. During totality red flames called prominences, many thousands of miles high, are seen shooting out into the corona; these also are invisible under ordinary circumstances because of the glare of sunlight in our atmosphere. By an ingenious arrangement, however, discovered independently by Professor Lockyer and M. Janssen in 1868, prominences may now be detected and their heights measured without an eclipse.

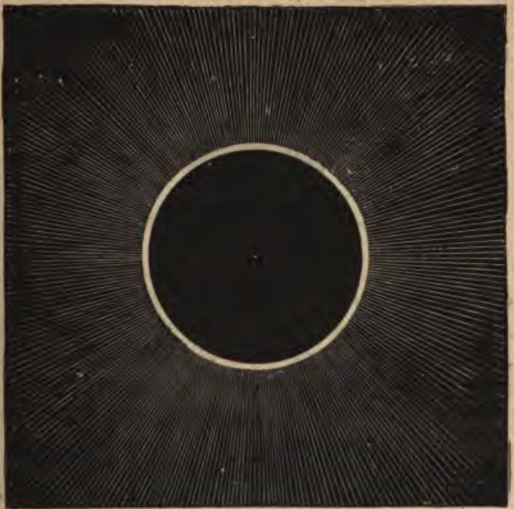


Fig. 40. Annular Eclipse of the Sun, as observed at Canea, on June 17, 1890.

If the moon passes exactly between the earth and the sun, as in a total eclipse, and the apparent diameter of the moon is less than that of the sun, it is evident that the whole of the sun's disc cannot be covered, and a ring of light will surround the dark shadow. This is called an annular, that is ring-shaped, eclipse (Fig. 40). We have shown that the moon's orbit is an ellipse and has a point of nearest approach to the earth (perigee), and a point of greatest distance (apogee). It is to this fact that we have to refer the cause of annular eclipses. When the moon is farthest from the earth her shadow is not long enough to reach the earth and she looks smaller than the sun, hence an observer situated in a line with the centre of the shadow sees a ring of light surrounding it.

If the moon does not pass centrally over the sun's disc then only a portion of the latter is covered up and a partial eclipse occurs (Fig. 41).

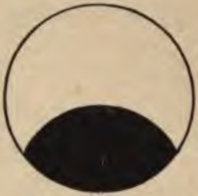


Fig. 41. Partial Eclipse of the Sun, as observed at London, on June 17, 1890.

One other point should be noted, namely, the frequency of eclipses. Solar eclipses are really more frequent than lunar eclipses, being in the proportion of 3 : 2, but we have seen that such eclipses are only visible over a very limited area. On the other hand, lunar eclipses are visible over a whole hemisphere of the earth, hence they are more usual at any one place than eclipses of the sun. It is interesting to note that there cannot be more than seven eclipses in a year nor less than one. There may be three lunar eclipses in a year but no more, and there may be none. The average number of eclipses is four, two lunar and two solar.

GENERAL SUMMARY OF CHAPTER VI.

The Moon's Surface is pitted all over with craters resembling the volcanic craters on the earth but much larger, many of them being fifty or sixty miles across.

The Moon has no Atmosphere for :—

(1.) All parts of the moon appear equally sharp and well defined without any haziness.

(2.) When the moon passes in front of a star, the star disappears instantaneously behind it and retains its full brightness right up to the moment of disappearance.

ELEMENTS OF THE MOON'S ORBIT.

Mean Distance	238,840 miles
Sidereal Period	27d. 7h. 43m. 11·5s.
Synodic Period	29d. 12h. 44m. 2·7s.
Inclination of Orbit to the Ecliptic	5° 8′ 40″
Eccentricity of orbit	$\frac{1}{20}$
Diameter	2162 miles
Mass, in terms of the earth's mass	$\frac{1}{80}$
Volume " " Volume	$\frac{1}{49}$
Relative Density, or Specific Gravity	3·43

The Sidereal Revolution of the Moon is the time occupied in passing from a star to the same star again as seen from the earth. Hence the moon's daily motion in degrees is 360° divided by a sidereal period that is about 13° 11′.

The Synodic Revolution of the Moon is the length of the lunar month, or the time taken by the moon to pass from full moon to full moon, new moon to new moon, or from any phase to the same phase again.

The Inclination of the Moon's Orbit is determined by observing its path among the stars during the month; sometimes it will describe a slightly larger arc than at other times, just as the sun, because of the inclination of the earth's equator to the ecliptic, describes a larger arc in summer than in winter.

The Relative Density or Specific Gravity of any body is its mass divided by its volume, hence the density of the moon compared with the earth is $\frac{1}{81} \div \frac{1}{49} = \frac{0{\cdot}0125}{0{\cdot}0204} = 0{\cdot}613$.

But the average density of our earth itself compared with water is about 5·6, hence the density of the moon compared with water is 0·613 of 5·6 or 3·43.

Perigee and Apogee.—The moon is in perigee when nearest to the earth; in apogee when farthest away.

Librations of the Moon:—

(1.) Libration in longitude enables us to see a little around the western edge of the moon when she is between perigee and apogee, and a little around the eastern edge when she is between apogee and perigee.

(2.) Libration in latitude enables us to see a little more of the moon's surface in a north and south direction.

(3.) Diurnal or parallactic libration is caused by the motion of an observer on the earth from west to east or from north to south, whereby he views the moon's surface from different stand-points.

The Phases or Changes of the Moon occur because the moon is an opaque body and only shines by reflected sunlight; one hemisphere, therefore, is light, the other dark and only that part of the illuminated hemisphere turned towards the earth at any time can be seen.

An Eclipse of the Moon is caused by the moon entering into the earth's shadow.

Duration of a lunar eclipse: about two hours. Phenomena seen: eastern limb gets somewhat darkened, then a shadow with a circular outline appears and eventually covers up the whole disc; during totality, however, a dull coppery-coloured disc is generally visible owing to the refraction of light by the earth's atmosphere, eastern edge then emerges and finally the whole disc appears.

An Eclipse of the Sun is caused by the moon's shadow falling upon the earth. Possible duration of totality: nearly eight minutes. Important—because of the number of observations that can only be made during a solar eclipse. Phenomena seen: the sun's face is slowly obscured until only a crescent of light is left, then darkness swiftly comes on, the corona and prominences become visible and bright stars appear.

Differences between Lunar and Solar Eclipses.—Duration of lunar eclipse—about two hours, solar—from a few seconds to nearly eight minutes. Lunar eclipses are visible over a whole hemisphere, solar only within a belt having an average diameter of 100 miles.

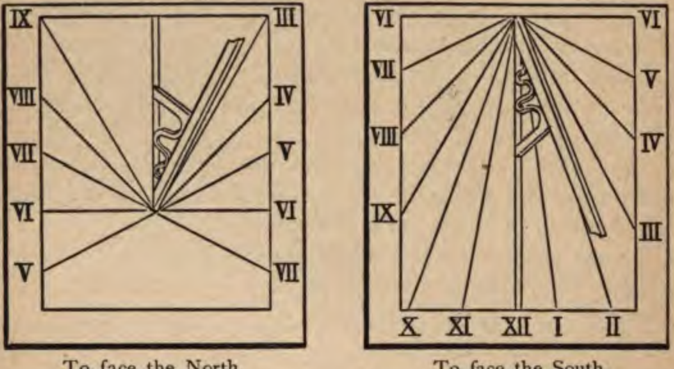
An annular eclipse of the moon is impossible because the earth's shadow, where the moon's orbit cuts it, always exceeds the diameter of the moon in breadth.

Lunar eclipses happen when the moon is in opposition (full moon), solar eclipses when it is in conjunction (new moon).

CHAPTER VII.

THE MEASUREMENT OF TIME.

The changing direction of the shadows of all objects as the sun crosses the sky is so manifest a phenomenon that the method of measuring time by means of the sun-dial is of great antiquity. The essential parts of a **sun-dial** are a projecting rod parallel to the earth's axis and called a *style*, and a plate of some kind called a *dial* to receive its shadow (Fig. 42). As the sun rises in the east the shadow falls to the west; with the movement of our luminary to the south the shadow passes towards the north, reaches its shortest length, is due north at mid-day when the sun is highest; and then passes eastward until sunset. At night the position of the stars relative to objects on the earth may be roughly used for the same purpose.



To face the North. To face the South.

Fig. 42. Sun Dials.

Clocks and watches are mechanical arrangements for measuring the flow of time. Some source of energy such as a suspended weight or a wound up spring gives motion to a pendulum or a balance wheel, which motion, by a proper train of wheels, is communicated to the hands of the clock or watch. The motion of the hands is so regulated that the

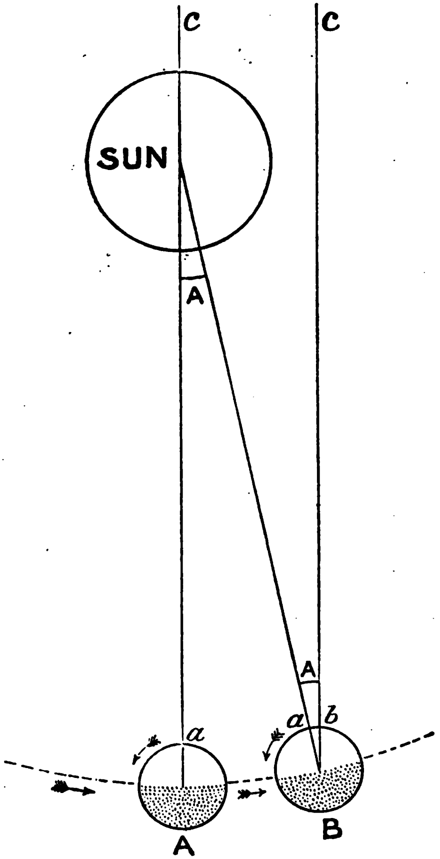


Fig. 43. Cause of the different lengths of the Solar and Sidereal Days.

interval of time which we call an hour indicated by them is a twenty fourth part of the average length of the day.

It has been stated that whereas the interval of time between two successive passages of a star across the same meridian is 23 hrs. 56 mins. 4 secs., the day as measured by the sun is four minutes longer. The reason for this difference will be seen from an inspection of Fig. 43. Let A represent the earth in a certain position in her orbit, and let the sun and an infinitely distant star be just crossing a meridian together; when the same star comes on the meridian again the earth will be in the position B, but the sun will not come on the meridian until the earth has rotated through the arc *a b*, and hence the solar day is longer than the sidereal day by the time the earth requires to rotate through this arc. The lines *a c* and *b c* are practically parallel to each other because the stars are so far away, so that the earth always rotates through exactly 360° in the time that elapses between two successive meridianal passages of the same star, and therefore a sidereal day is always of the same length; in order to form a solar day, however, the earth has to rotate through the angular distance, measured at the sun, which it has passed over in its orbit, in addition to the 360° through which it rotates to bring the star on the meridian. This angle is 1° and the earth takes four minutes to rotate through this amount. But we have shown that the earth moves with varying speed in its orbit, so that the angle at the sun through which it moves in a sidereal day must differ, and the additional amount through which the earth has to rotate to form a solar day must differ also, that is, solar days are not always of the same length. It would therefore appear that for a uniform standard of measurement of time a sidereal day is the most simple, but the southing of the sun is so much more manifest a phenomenon that it has always been utilized. **Apparent solar time** is indicated by a sun-dial, but a clock or watch to keep this time would have to change its rate from day to day. For the purposes of convenience the lengths of all the days in a year are added up and the *average* length found, this is called the **average or mean**

solar day, and is used for all purposes in civil life as it marks the recurrence of daylight and darkness and does not differ considerably from the actual length of the day.

The **civil day,** or 'day' as generally understood, is of the same length as the mean solar day. It is reckoned from midnight to midnight—through 1 a.m. to 12 a.m., and 1 p.m. to 12 p.m. The **astronomical day** is reckoned from mean noon to mean noon through 24 hours, and has no a.m. or p.m. It begins at 12 a.m. civil time, hence the civil day is always 12 hours in advance of the astronomical day.

All clocks and watches should keep mean solar time, and the meaning of the expression **Greenwich mean time** will now be understood to be the time as regulated by the average interval between two successive passages of the sun across the Greenwich meridian. The difference between mean and apparent time depends upon the eccentricity of the earth's orbit and the obliquity of the ecliptic—that is, the inclination of the plane of the earth's equator to the plane in which it revolves round the sun.

On account of the first cause the apparent easterly movement of the sun in the ecliptic is continually varying throughout the year. It is greatest in January when the earth is nearest the sun, and least in June when the earth is furthest away, hence the day as measured by the sun-dial is longer in the former than in the latter month. In consequence of the second cause the apparent eastward motion of the sun is greatest at the solstices and least at the equinoxes, and is, therefore, subject to a constant variation between these times.

Astronomers imagine an average or mean sun to move at a uniform rate along the celestial equator, and, since the rate of the true sun is not constant throughout the year, sometimes sun-dial time is behind mean time, sometimes the two coincide, and sometimes sun dial time is ahead. The following are the dates of coincidence and the maximum amounts by which the two times differ :—

February	11	...	True Sun	14 mins. 32 secs. slow.
April	15	...	"	Correct.
May	14	...	"	3 mins. 54 secs. fast.
June	14	...	"	Correct.
July	26	...	"	6 mins. 12 secs. slow.
Sept.	1	...	"	Correct.
Nov.	2	...	"	16 mins. 18 secs. fast.
Dec.	24	...	"	Correct.

So that the sun is constantly falling behind the clock, catching up to it, and passing it; and the difference between apparent or sun-dial time and mean or clock time is called the **'equation of time.'** The equation of time to be added to or subtracted from Greenwich apparent noon in order to convert it to mean time is given for every day in the year in the 'Nautical Almanac' and other publications.

The **week** is not an astronomical division of time like the day, month or year; but there is little doubt that its length was suggested by the motion and phases of the moon. The time taken by the moon to pass from half to full and from full to half again must have been the origin of our week of seven days.

It has been shown in a previous chapter that the **month** is a period of time regulated by the motion of the moon. A **lunar or synodic month** is the interval of time that elapses between two successive appearances of the moon in the same position relatively to the earth and sun. The length of the lunar month is variable on account of the varying speed of the earth in its orbit. The average length is $29\frac{1}{2}$ days. A **sidereal month** is the interval between two successive conjunctions of the moon with the same star, that is, $27\frac{1}{2}$ days. A synodic month is longer than a sidereal month for a reason similar to that which is the cause of the difference in the solar and sidereal day. Let the earth, moon, sun, and a distant star be in a straight line as indicated by the left hand arrow in Fig. 44. When the moon comes again in front of the same star, the earth will have moved on in its orbit and it is not until two days later that the moon comes in front of the sun again.

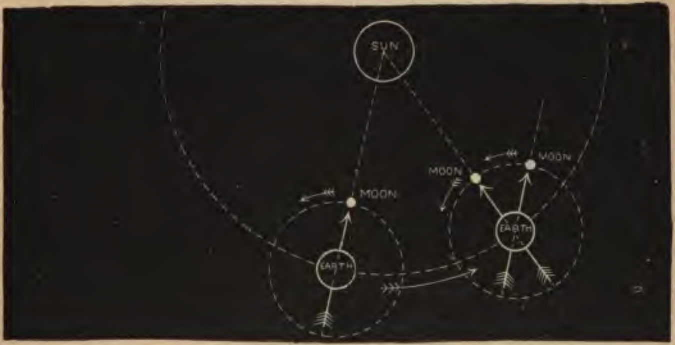


Fig. 44. Cause of the different lengths of the Lunar and Sidereal Months.

The **calendar month** is the one employed in civil life and used in the almanacs. Since the moon revolves round the earth in 27½ days she makes a little more than 13 revolutions in a year of 365 days. On account of the revolution of the earth, however, in this time there are only 12½ lunar months of 29½ days. At one time twelve lunar months, that is, 354 days, were taken to make up a year, and since this was 11 days short, an extra month was added to alternate years. Now, however, calendar months are employed, that is, months containing a whole number of days, as 28, 30 or 31, and twelve of these months make up our year. The lunar year of 354 days is still in use among the Moslems.

The **sidereal year** has been stated to be the interval of time that elapses between two successive conjunctions of the sun with the same fixed star, and is 365 days 6 hrs. 9 mins. 9 secs. long. The **tropical** or **equinoctial year** is the interval of time that elapses between two successive passages of the sun through the same equinoctial point. Owing to precession the equinoxes advance to meet the sun $50''\cdot2$ in every year, hence the sun passes through the equinoxes sooner than it would otherwise do, and hence the tropical year is about twenty minutes shorter than the sidereal year. Its exact length is 365 days 5 hrs. 48 mins. 46 secs. The **anomalistic year** is the time that elapses between two successive passages of the sun through the perihelion or aphelion point. Its length is 365 days 6 hrs. 13 mins. 48 secs., that is, nearly five minutes longer than the sidereal year, on account of an eastward movement in the heavens of the points of reference.

The **civil year** is the one used in ordinary life for the measurement of time. Since the times of the seasons are regulated by the tropical year, the length of the civil year is also referred to it. But the tropical year does not consist of an exact number of days, hence, in order that the average civil year should be equal in length to the tropical year, it must sometimes be longer and sometimes shorter.

The times of the solstices and the equinoxes are so well marked that they have been used to mark divisions of the year from time immemorial. Originally the year began at the summer solstice in Attica and at the autumnal equinox in Macedonia. Our present year has been derived from that of Rome, where the year commenced at the winter solstice. The month which followed that in which the winter solstice occurred was named January. Julius Cæsar (B.C. 46) found that the calendar was in such confusion that January occurred during the autumn, so he made a revision of the state of things, brought January back to nearly its present position with reference to the winter solstice, and instituted a year of 365 days, prescribing that one day should be added every fourth year, so that the average year should be 365¼ days long. This caused the spring equinox to fall about March 25. The immediate successors of Cæsar arranged the number of days in the months as we now have them.

The **Julian calendar**, as this admirable arrangement of Cæsar's was called, was subsequently found to be 11 mins. 14 secs. longer than the tropical year, the proportion being as follows:—

	d.	h.	m.	s.
Julian year	365	6	0	0
Tropical year	365	5	48	46

Consequently, in the 16th century the equinox occurred 11 or 12 days sooner than it should have occurred according to the calendar.

To bring back the church festivals to their original position in the year—or more exactly to their position at the time of the Council of Nice (A.D. 325), when the equinox fell on March 21 and it was decreed that the first Sunday after the first full moon next following the spring equinox was to be Easter Sunday—Pope Gregory XIII. directed that the following reforms of the calendar should be made :—

(1.) October 5, 1582, was called October 15, thus bringing the spring equinox to March 21.

(2) Leap years to be as heretofore, except that the closing year of each century (1600, 1700, etc.) is only to be leap-year when the number of centuries is divisible by four. This change gives three days less in 400 years than the Julian calendar. The average length of the civil year thus becomes 365·2425 days, whilst that of the tropical year is 365·242216 days. There is therefore a further correction of one day to be omitted every 4,000 years, or more accurately every 3,846 years, in order to make the civil and the tropical year exactly equal.

The **Gregorian calendar** was adopted in England in 1752, but has not been adopted yet by the Russian church or people.

GENERAL SUMMARY OF CHAPTER VII.

The **True or Apparent Solar Day** is the time that elapses between two successive appearances of the sun on the meridian of a place, and is indicated by a sundial.

The **Mean Solar Day** is twenty-four hours long, and is the average of the lengths of all the true solar days throughout the year.

The **Mean Astronomical Day and the Civil Day** are both of the same length, but the former is reckoned from mean noon to mean noon through 24 hours whilst the latter begins at the preceding midnight and is reckoned through 12 hours before noon and 12 hours after noon.

The **Difference in the Lengths of the Solar Days** throughout the year is due to—

(1) The eccentricity of the earth's orbit.
(2) The obliquity of the ecliptic.

The **Equation of Time** is the amount to be added to or subtracted from true solar time to convert it to mean solar time or the time indicated by clocks.

The **Lengths of Different Months** are as follows:—

	d.	h.	m.	s.
Lunar or synodic month ...	29	12	44	2·84.
Sidereal month	27	7	43	4·71.

Calendar months from 28 days to 31 days.

The **Lengths of the Different Years** are as follows:—

	d.	h.	m.	s.
Sidereal Year	365	6	9	9.
Tropical or Equinoctial year ...	365	5	48	46.
Anomalistic year	365	6	13	48.

The Civil year begins on January 1st, and consists of 12 months, each containing a whole number of days.

CHAPTER VIII.

TIDES.

ALMOST all the inhabitants of a maritime country like Great Britain have observed the constant and regular rising and falling of the waters of the sea, known as tides. For about six hours the sea slowly rises, then falls—to rise and fall again, thus reaching the highest and lowest points twice in a day. Indeed, the interval of time between **high water**, or flood, and **low water**, or ebb, is so well defined that in some places time, instead of being measured by the movements of the sun, is measured by the tides; a journey is said to take a certain number of tides for its completion, when we should say a certain number of days; indeed, the natives of Tahiti and the Society Islands distinguish the hours of the day by reference to the state of the tide, using such terms as—'Where is the tide?' when we should say—'What is the time?'

It was noticed at a very early period of human history that a connection existed between the tides and the motion of the moon, and the fact that high tides always occur when the moon is in a certain part of the heavens made it very manifest that they were due to lunar influence. Hence it is that vague notions have always filled the minds of men as to the nature of the disturbing influence; but it was left to Newton to demonstrate the true cause of the phenomenon.

It will doubtless be remembered that the moon rises, passes the meridian, and sets fifty minutes later every day. Similarly, the times of high and low water get fifty minutes later on an average every day. Or, to put it in another way, the average interval between two successive passages of the moon across the meridian is 24 hrs. 51 mins. Sometimes it is more, sometimes less, but this is the length of the average or mean lunar day. In like manner, the average interval between alternate high or low water is also 24 hrs. 51 mins. In this interval two high and two low tides occur, so that high and low water occur when the moon is not visible; hence the explanation that tides are produced by the attraction by the moon of the water under it is not sufficient, for, if such were the case, only one tide a day would occur.

We will give the theory of tides worked out by Newton—now called the statical theory—and show that it is sufficient to explain the most prominent phenomena.

Consider the earth at rest and the moon to occupy her position relative to it, that is, 240,000 miles away. Now it may be easily proved that the nearer two bodies are together the greater is the attraction between them. In more exact terms the force of gravitation varies 'inversely as the square of the distance' between the attracting bodies; hence if the distance of the moon from the earth were doubled the attraction between the two bodies would be $\frac{1}{4}$ of what it is at present; if the distance were trebled the force would have $\frac{1}{9}$th of its present value. From this law it is evident that the effect of the moon's attraction upon the side of the earth near it is greater than the attraction at the earth's centre, and the effect in the case we are considering is that the waters are pulled away from the solid earth and heaped up under the moon into a mass having a spheroidal form (Fig. 45). Similarly, the centre of the earth is nearer the moon than the waters on the further side, hence the solid earth is drawn towards the moon with a stronger force than the waters on the side away from the moon are, and the effect is to leave the latter on the opposite side bulged out in exactly the same way as the waters on the side nearest the moon. If the earth were at rest this lemon-shaped projection would travel round our globe with the moon; high water would always occur exactly under the moon and 180° from it, and low water at all places halfway between the two, that is, 90° from either.

At first sight it would appear that the sun's enormous mass ought to have a much greater effect in causing tides than that incomparably much smaller body, the moon, and we have now to show why this is not the case. The radius of the earth is about 4,000 miles long, the average distance of the moon 240,000 miles, hence it would take 240,000 ÷ 4,000, or 60 times the earth's radius, to reach to our satellite. For convenience, we will take the average distance of the sun as 96,000,000; this in terms of the earth's radius is $\frac{96{,}000{,}000}{4{,}000} = 24{,}000$. So that in the case of the moon the radius of the earth is $\frac{1}{60}$ of the distance between it and the earth, whilst in the case of the sun it is only $\frac{1}{24000}$ part of the whole.

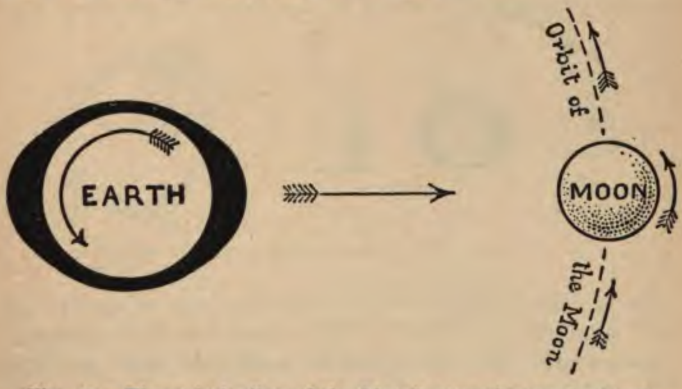


Fig. 45. Theoretical effect of the Moon's attraction on the Earth.

It is evident, therefore, that the difference of attraction upon the earth's surface and centre, which we have shown is the cause of tides, is much greater in the case of the moon than in the case of the sun, and hence the tidal effect of the moon is greater than that of the sun.

The student should guard himself against thinking that the moon's tidal effect is greater than the sun's because the former body is nearer the earth, for if the effect simply depended upon distance the sun would predominate. It is the *differential attraction* of the sun and moon upon the earth's centre and the waters at the surface that is the cause of tides. The sun really exerts an attracting force upon the earth as a whole which is 200 times greater than the force exerted by the moon; its power of raising tides, however, is only about $\frac{2}{5}$ that of the moon. To make this clear conceive our globe covered with water; then the difference of level of the water under the moon and 90° from it would be 2 feet, owing to the attraction of the moon. If the sun only acted it would produce a difference of level of about $9\frac{3}{4}$ inches. Thus the moon's tide is 24 inches, and the sun's tide is $9\frac{3}{4}$ inches; therefore the action of the moon in producing tides is to the action of the sun in producing tides as 24 is to $9\frac{3}{4}$, that is, nearly as 5 is to 2. If, then, the sun and moon pull together and their two tides are added, an unusually high tide will occur; similarly, if they act against each other, the high tide will be lower than the average. The sun plus moon tides would, therefore, have a height that may be proportionally represented by $5 + 2 = 7$, and the sun minus moon tides will have a proportional height of $5 - 2 = 3$. The times at which the sun and moon act together are represented in Fig. 46. The moon is there shown in two positions in its orbit. When it is new moon, the effect of the sun in producing tides is added to the lunar effect; similarly, when the moon arrives at the position of full moon, the solar and lunar

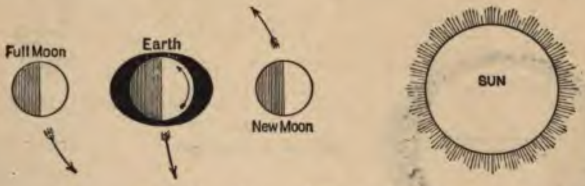


Fig. 46. Cause of Spring Tides.

influences are added together. When, however, the moon is in quadrature, as shown in Fig. 47, it is acting against the sun. We know that if the moon existed alone there would be a difference of level of 2 feet in the water under it and ninety degrees from it. But the sun is also exerting an effect and its tide is partially filling up the depression due to the moon's action. The lunar tide, however, being greater than the solar tide, preponderates, and a low 'high water' occurs under the moon. It is clear, therefore, that in a lunar month, in addition to the daily tides, there will be two very high and two very low tides, separated by a fortnight. The highest tides of the month occur at or near new and full moon, and are called **'spring tides'**; the lowest tides of the month occur when the moon is in her quarters, and are called **'neap tides'**; and it is evident that the average spring tide is to the average neap tide as (5 + 2) : (5 − 2), that is, as 7 : 3.

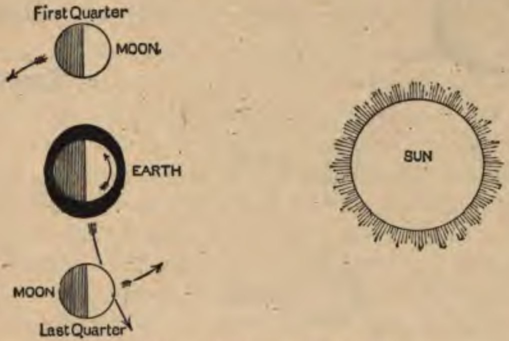


Fig. 47. Cause of Neap Tides.

It would appear that the interval between two tides should always be 24 hours 51 mins.; this, however, is not the case. When the moon occupies the position A shown in Fig. 48 the heap of water will not be exactly under it, but because of the sun's attraction will assume the form indicated. In such cases that is, before new moon, high water occurs a little before its usual time and is said to '**prime.**' A few days after new moon, however, our satellite will occupy the position B in the figure, and high water will occur a little later than usual—the tides '**lag**' behind. In a like manner the same effect will occur shortly before and after full moon. We have said that the average interval between the corresponding tides of successive days is 24 hrs. 51 mins., but the lagging and priming each make a difference of about 13 minutes in the tidal interval, so that at the time of priming the interval may only be 24 hrs. 38 mins. and at the time of lagging may be as much as 25 hrs. 4 mins.

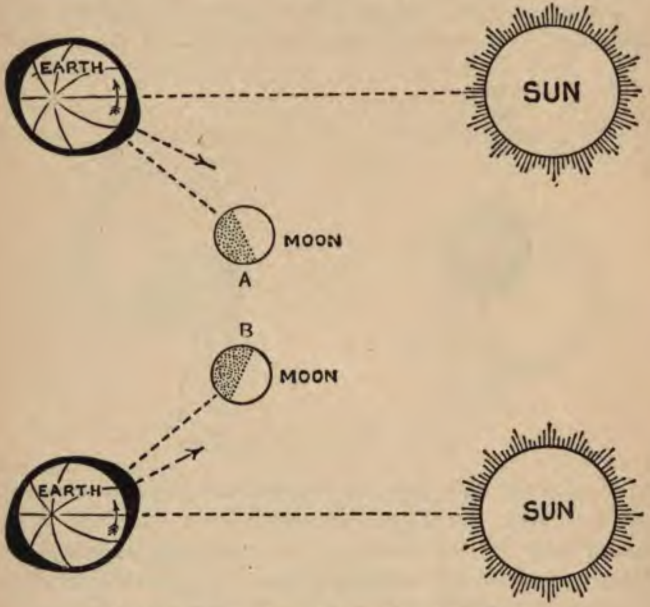


Fig. 48. Priming and Lagging of the Tides.

It has been previously shown that the sun moves in a year from the tropic of Cancer 23½° north of the equator, to the tropic of Capricorn, 23½° south of it, and back again. From this it will be easily understood that when the sun is over the tropic of Cancer the tidal prominence raised by it will have the greatest height at that point, and that it will move with the sun north and south of the equator during the year. The change in the height of the tides due to the change in the sun's declination is not however considerable.

In a previous chapter it was shown that the moon's orbit is inclined 5° 8′ to the plane of the ecliptic, hence, since the sun moving in the ecliptic wanders 23½° north and south of the equator because of the inclination of the earth's axis, the moon may move from the equator to a distance of 23° 30′ + 5° 8′, that is, 28° 38′, and carry its tidal prominence with it.

Twice a year, however, at the spring and autumnal equinoxes, the sun is over the equator, hence for the new and full moons that occur at these times, when both the sun and moon are nearly vertically over the equator and their two prominences are almost exactly one on the other, unusually high tides happen and such are known as the **equinoctial spring tides.** It is evident also that at the time of eclipses, when the sun and moon are in a line, unusually high tides will occur, and that when the moon is in perigee, that is, nearest to the earth, its effect will be greater than when it is in apogee. For the same reason the tides in winter should be higher than in summer because the earth is then nearer the sun.

It has been observed that the two tides of the day are not equal but differ in magnitude. This is rightly called the **diurnal or daily inequality.** The cause of this inequality is manifest from Fig. 49. The moon in a month gets about 5° below and above the ecliptic, hence the tidal prominence will move continually over different latitudes. To take an example, high tide occurs at a place C, and about twelve hours later C will have been carried by the earth's rotation so as to be at C¹, under the lower high tide. From this it is evident that the two tides can only be equal in magnitude when the sun and moon are on the equator, and when they both act in the same direction upon the earth. The effect is well seen in the Gulf of Mexico, where it causes only a single tide to occur when the moon is some distance north or south of the equator. Again, owing to this cause, twice a month, when the moon is highest north and lowest south of the ecliptic, the two tides of the day observed in high latitudes in the Pacific Ocean are very different in magnitude.

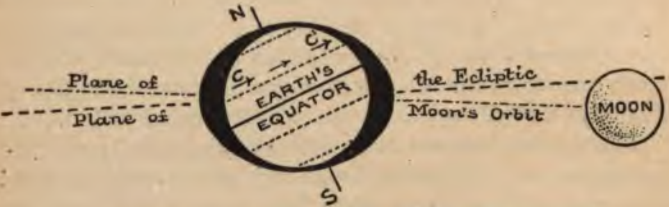


Fig. 49. Diurnal Inequality of the Tides.

So far we have described the phenomena that would occur if the waters on the earth everywhere yielded immediately to the attractive force of the sun and moon. This, however, is not the case. Water, like everything else, requires time for a force to set it in motion. Hence, even if the earth were covered uniformly with water, high tides would not occur directly under the moon but some hours after it had passed the meridian; the moon would drag high tides after it at a certain angle, and the interval of time between the meridian passage of our satellite and high water would be the same all over the earth. But such considerations are entirely theoretical, and the phenomena would only occur if the tidal wave could flow everywhere without interruption. The actual phenomena of the tides are infinitely more complicated; the unequal depths of the ocean in various localities, the irregular conformation of the land, the varying widths and lengths of the channels, the action of the wind and many other causes make the interval between the moon's meridional passage and high tide different for different places on the earth. Indeed, this interval can never be theoretically determined, and must be found by observation. The time that elapses each day between the passage of the moon across the meridian and high water is called the '**luni-tidal interval.**' These intervals vary slightly for reasons we have before indicated. The average of all the intervals in a semi-lunation, that is, the average interval between the time of high water and the preceding passage of the moon across the meridian, is called the average or '**mean establishment of a port.**' The following is a list of some establishments—

	hour	mins.
Aberdeen	1	0
London Bridge	1	58
Land's End	4	30
Falmouth	4	57
Swansea Bay	6	10
Bristol	7	13
Southampton	10	30
Belfast	10	43
Dover	11	12
Brighton	11	15
Liverpool	11	23

Since the 'tide interval' between any two places is always nearly the same, if the time of high water in any port be known on any day that at any established port may be calculated.

The difference of level between high and low water is called the '**range of the tide.**' This range is different for different places, and is chiefly dependent upon the shape of the land. It is easy to understand that in deep estuaries or creeks opening in the direction of the tidal wave like a funnel the range is very much greater than elsewhere, for as the width of the creek decreases the height of the tidal wave must increase and the greater must be its velocity. As examples of places so situated, that of Chepstow, in the Bristol Channel, may be quoted; there the difference between high and low water, or the tidal range, is from 60 to 70 feet. The range in the Bay of Fundy is about 100 feet; at St. Malo and Bristol it is 40 feet; the London Docks, about 22 feet; Liverpool, about 15 feet, and Portsmouth and Plymouth, 12 feet.

In estuaries that are wide at the mouth and contract like a funnel the converging tidal wave rushes up the river like a wall of water. Such great waves are called **bores**. Some rivers remarkable for their tide-bores are the Severn, Seine, Amazon, and the Hoogly branch of the Ganges, where the bore travels 70 miles in four hours at a height of about 7 feet. The bore of the Tsien-Tang in China is said to have a front about 30 feet high, to be four or five miles across, and to advance at the rate of about twenty-five miles an hour.

Where promontories or headlands jut out into the sea the tidal range is frequently small; thus at Wicklow it is only 4 feet, at Weymouth 7 feet, and at the Needles 9 feet.

In very large open tracks of water like the Pacific and Atlantic Oceans the range rarely exceeds 5 or 6 feet, and in narrow enclosed seas like the Baltic and Mediterranean, the tidal range is very small; indeed these seas are practically tideless. At Toulon the range is only about a foot, at Porto Rico (St. Juan) and in the Mediterranean about 18 inches, and at St. Helena 3 feet.

It should be thoroughly understood that there is no actual transfer of water by the tidal wave like there is in a river. The effect of the tidal action of the sun and moon is merely to cause the particles of water to rise and fall, and not to give them a motion of translation. It is well known that if one end of a rope be shaken a wave passes along it, yet each part of the rope only moves up and down. The motion of the tidal wave is precisely similar. In shallow depths of water an accumulation of such motion occurs and produces **tidal currents** like those on the English coast.

Since, however, the force producing tides acts everywhere, the height of water in lakes and land-locked seas should be somewhat affected. In the Caspian Sea and in Lake Superior the variation in level is imperceptible; but a tide of about 1¾ inches has been detected in Lake Michigan, and one of about ¾ of an inch in Lake Erie.

The height of tidal waves is affected considerably by the state of the atmosphere. A barometer indicates the pressure of the atmosphere—when it is low the pressure is low, when it is high the pressure is high—and it is found that the higher the barometer the less is the height of the tidal wave, and conversely, the lower the barometer the higher is the level of the water. At Liverpool a depression of 1 inch in the barometric height means a rise of 10 inches in the elevation of the Mersey high water mark, and at the London Docks a difference of 1 inch in barometric height means a difference of about 7 inches in the height of the tide. The tide is also liable to be considerably affected by winds.

If the surface of the earth were uniformly covered with water the tidal wave would follow the moon and consequently travel round the earth in 24 hrs. 51 mins. As the circumference of the earth at the equator is 25,000 miles, hence the velocity of the wave would be about 1,000 miles per hour. The actual velocity, however, is nowhere equal to this and is very different at different places because of the varying depths of the ocean. It is easy to understand why high velocities are almost invariably found to exist where the water is deep, while low velocities occur in shallow water; for the tidal wave moves with greatest freedom where there is least obstruction, and accordingly the uninterrupted zone of the Antarctic Ocean may be said to be its cradle.

The following are some of the velocities of the tidal wave—

	miles per hour.
In the Atlantic	700
Azores to Cape Clear	500
Cape Clear to Duncansby Head... ...	160
Buchan Ness to Sunderland	60
Scarborough to Cromer	35
North Foreland to London	30
London to Richmond	13

The following course of the tide to the English Coasts is from Keith Johnston's Physical Atlas. 'A high tide leaving the Cape of Good Hope about 1 passes up the Atlantic, reaches the Equator at 6, the Tropic of Cancer at 9, the Azores at 12; it stretches from Cape Finisterre to Iceland about 3, and is 1° of latitude S.W. of the Land's End about 4. The Northern portion sweeps round the Isle of Lewis at 7 and the Orkneys at 8, at 11 it reaches Peterhead and Egersund in Norway, at 12.30 Aberdeen and the Naze, at 2 Edinburgh, at 4 Flambro' Head, at 7 Boston, and at 8.30 Great Yarmouth. A second portion passes up St. George's Channel, reaching St. David's Head at 6, the Isle of Man at 10, Belfast and Port Patrick at 11. The Southern portion passes up the English Channel, reaching Falmouth and Morlaix at 5, Portland Bill and Cape la Hague at 7, the Isle of Wight and Harfleur at 8, Deal and Calais at 11, Ramsgate and Dunkirk at 12, London Bridge at 2.15, Yarmouth at 3, and the Coast of Jutland at 1.'

Although the velocity of the tidal wave is so different at different oceanic depths and subject to considerable variation on account of the configuration of the land, the time of high water may of course be the same at different places. If we take a map of the earth and draw lines upon the surface of the ocean connecting those places which have their high water at the same moment of time, we get what are called **co-tidal lines.** Observations of high and low water are impossible in mid-ocean, and the approximate position of the co-tidal lines can only be determined by observations at the islands and coasts. In the case of the British Isles, however, this uncertainty does not exist, and the co-tidal lines are shown in Fig. 50.

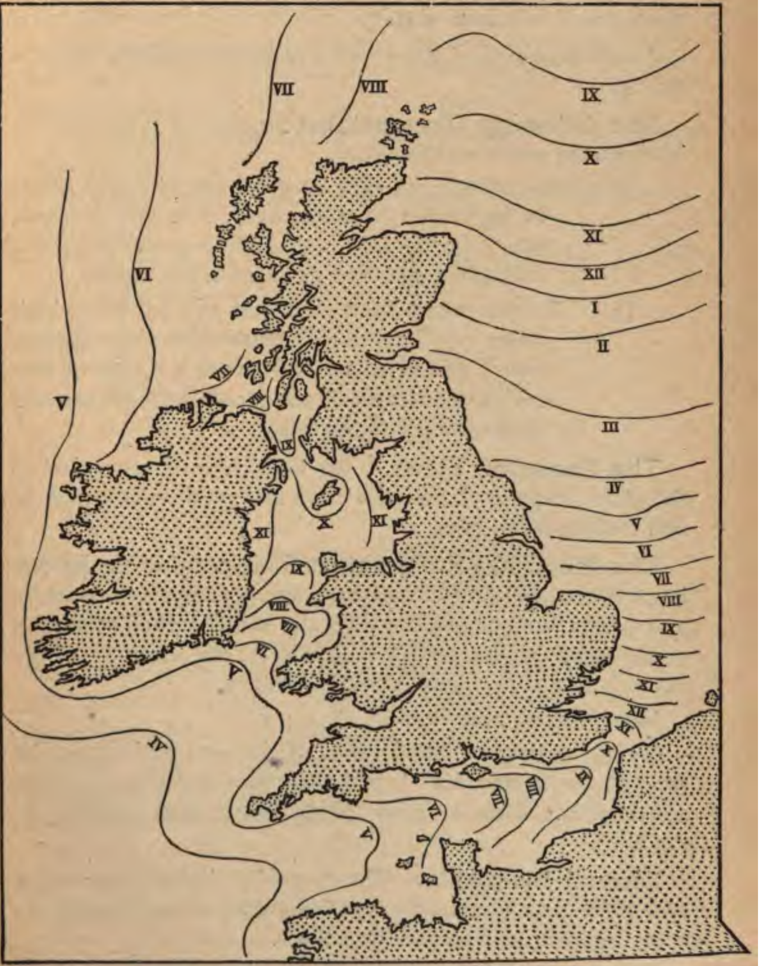


Fig. 50. Co-Tidal lines around the British Isles.

GENERAL SUMMARY OF CHAPTER VII.

When a tide reaches its highest it is said to be **high water**, when lowest it is **low water.**

A tide **flows** when the water is rising and **ebbs** when it is falling.

The following Circumstances point to a connection between the moon and the tides.

(1.) The average interval between two alternate times of high water or of low water is 24 hrs. 51 mins., which is the time that intervenes between two successive meridian passages of the moon.

(2.) Twice a month soon after new and full moon high water reaches a higher mark than usual (spring tides), and twice a month about the time of first and last quarters of the moon the tides are less than ordinary (neap tides).

The Cause of Tides is the difference of attraction of the moon and sun on the solid earth and on the water nearest and farthest from them.

The Moon has the greatest Tide-producing Effect because the difference of its attraction upon the earth's surface and centre is much greater than the difference of attraction of the sun, for the earth's radius is $\frac{1}{60}$ the distance of the moon but only $\frac{1}{24000}$ of the sun's distance.

Moon's effect : Sun's effect :: 5 : 2.

Owing to the combined effect of the sun and moon the spring tides occur a little before their time and the neap tides a little after. This is called the **priming and lagging** of the tides.

Diurnal Inequality.—The two tides that occur in a day vary in height and are only equal when the sun and moon are *on* the equator and act in a direct line.

Equinoctial Spring Tides.—The spring tides are greater a short time before the vernal equinox and after the autumnal equinox than at any other time of the year, because the sun and moon then act most directly over the equator.

The Mean Establishment of a Port is the average interval of time that elapses between the passage of the moon across the meridian of the port and high water.

The Range of the Tide is the difference of level between high and low water.

A Tidal River is one visibly affected by the ebb and flow of the tide.

Co-tidal Lines are lines joining those places on the earth which have high water at the same time.

CHAPTER IX.

THE NATURE AND CONSTITUTION OF THE ATMOSPHERE.

WHEN the wind blows we are made conscious of the presence of an invisible something surrounding us in all directions, lightnings flash, thunders roll, torrents of rain, hail and snow fall upon the surface of our globe, and the region where all these things occur is called the atmosphere, that is, the vapour-sphere. Since this mass of matter has a material existence, it must have weight, although previous to 1650 no one had demonstrated the fact. The method adopted in the determination of the weight of air is illustrated by Fig. 51. A globe of glass having a capacity of, say, a cubic foot has the air pumped out of it and is weighed; the stop-cock is then turned and air rushes in and fills up the globe. On weighing again, if the experiment be made at sea level and at the temperature of freezing water, the increase of weight of the globe will be about an ounce and a quarter; this is therefore the weight of a cubic foot of air. A cubic foot of water weighs 62·4 lbs.

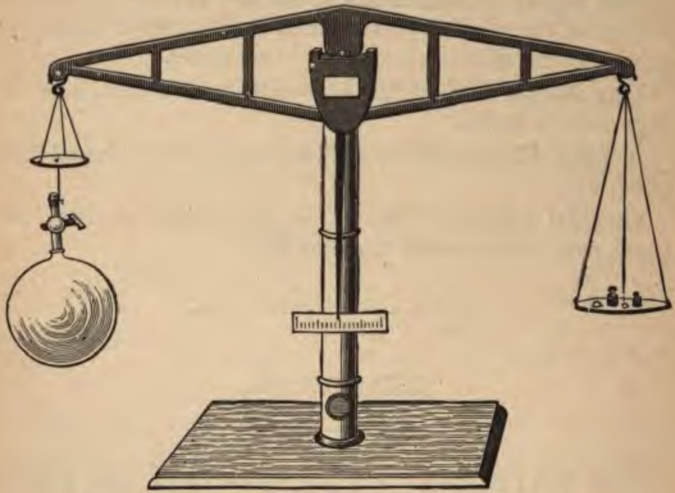


Fig. 51. Method for determining the weight of Air.

We may measure the weight or pressure of the atmosphere in another way. Take a glass tube about 3 feet long closed at one end, open at the other—about ¼ inch in diameter is a convenient size—turn the tube up and fill it with mercury, put your thumb on the open end and place the tube upright in a cup or basin containing mercury (Fig. 52), take the thumb away; the mercury will fall a little in the tube and will then remain stationary, at a height of about 30 inches; it is evident therefore that something must balance the weight of the mercury or it would fall down the tube, and this balancing agent is the pressure of our atmosphere. The atmosphere is pressing down on the surface of the mercury in the basin and so keeping up the column of mercury in the tube. Conceive a tube having an area of a square inch to rise from the sea shore to a point in the atmosphere where the air is so thin as practically to have no weight, and let an exactly similar tube contain 30 inches of

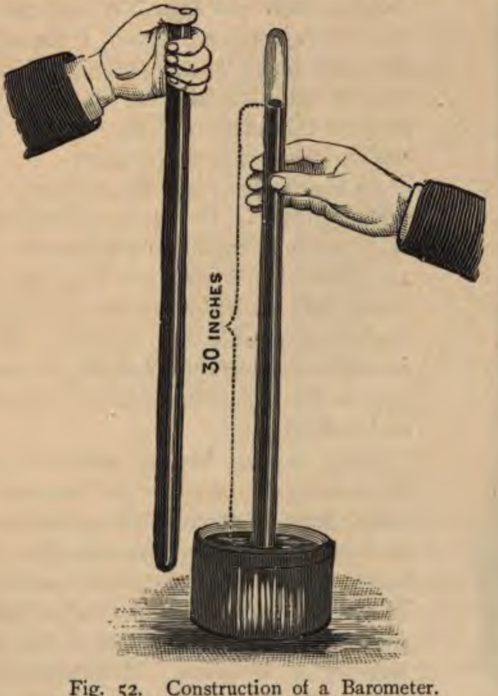


Fig. 52. Construction of a Barometer.

of mercury. The 30 inches of mercury would be found to weigh the same as the long tube of air, and since a cubic inch of mercury weighs about half a pound, 30 cubic inches weigh 15 lbs., that is to say, when there is a difference of level of 30 inches between the mercury in the tube and in the basin the atmosphere is pressing on all sides with a force equal to the weight of 15 lbs. on every square inch. Of course, if we ascend into the atmosphere by climbing a hill or going up in a balloon the pressure is not so much, and so the column of mercury falls somewhat; indeed, it is by observing the fall that balloonists know how high they have risen above the earth's surface. Again, if for any reason the atmosphere at any place gets lighter the column will also fall, and we shall see later on how this motion of the column indicates coming changes in the weather.

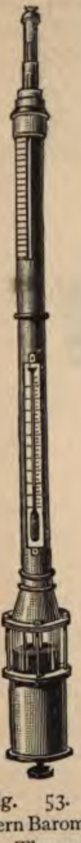


Fig. 53. A Cistern Barometer with Thermometer attached.

An instrument made like the above is called a **Barometer.** In Fig. 53, a barometer such as is used in scientific work is shown; the scale attached is for finding how high the mercury stands, and a determination of the height at any time is called a *reading*. When the mercurial column stands above 30 inches it is said to be high, when below 30 inches it is said to be low.

Other liquids besides mercury are used for making barometers, but require a much longer tube to contain the column necessary to support the atmospheric pressure. A water barometer has to be nearly 34 feet long. There used to be one at the Crystal Palace, and there is a glycerine barometer in the South Kensington Museum. If a hole were made in the top of any barometer tube, the air would get in and the liquid would fall until it was at the same level inside and outside the tube. From the description of the instrument it is evident that the part of the tube from the closed end to the top of the liquid in a barometer contains nothing but the *vapour* of the liquid of which it is made.

Another instrument to which we shall have occasion to refer is the **Thermometer.** As is generally known, it consists of a fine glass tube sealed at one end and having a bulb at the other, and containing some liquid—usually mercury or alcohol (Fig. 54). In the graduation of a thermometer it is first put in melting ice and a mark made on the glass at the same level as the surface of the liquid inside. The thermometer is then held in the steam of boiling water. The liquid in the bulb and tube expands until a point is reached where it remains steady, and another mark is then made on the glass tube. The length of tube between these two 'fixed points' may be divided into any number of equal divisions or 'degrees.' In England we use the Fahrenheit thermometer, in which the length is divided into 180 degrees; in France and for scientific work the Centigrade is used, in which the same interval is divided into 100 parts. In some parts the Reamur thermometer is used, in which the interval is divided into 80 parts (Fig. 55).

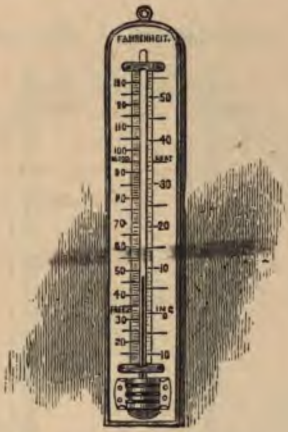


Fig. 54. A Thermometer.

That air is highly elastic and may be compressed may be seen by the action of an ordinary pop-gun. It therefore follows that since the earth is completely surrounded by an envelope of air the lower layers will be under greater pressure than the upper layers, for the same reason that when a pile of books lie upon a table the lowest book is under the greatest pressure. Balloonists have found that it is not possible to ascend more than about seven miles, because at that height the air is so thin as not to be sufficient to sustain life. There cannot, however, be any fixed limit to the atmosphere. If there were no atmosphere, as soon as our luminary sank be-

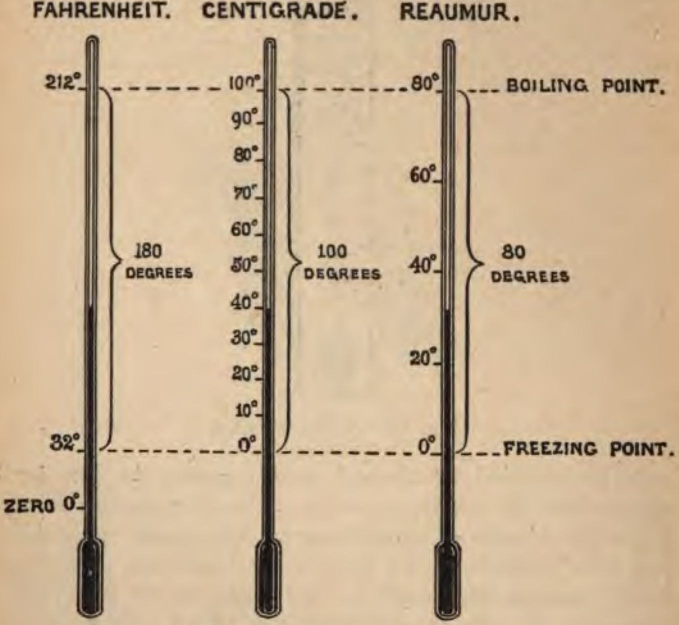


Fig. 55. Thermometric Scales.

neath the horizon a place would be shrouded in darkness. But we know that it is light some time after the sun has set and before he rises in the morning, and call these appearances **twilight** and **dawn** (Fig. 56). It is found that this illumination lasts as long as the sun is less than eighteen degrees below the horizon. The sun takes nearly two months to sink through this amount at the poles and two months afterwards he is again only 18° below the horizon. In latitude 50°, twilight lasts nearly two hours in March and October, nearly four hours at the end of May and as the sun does not get eighteen degrees below the

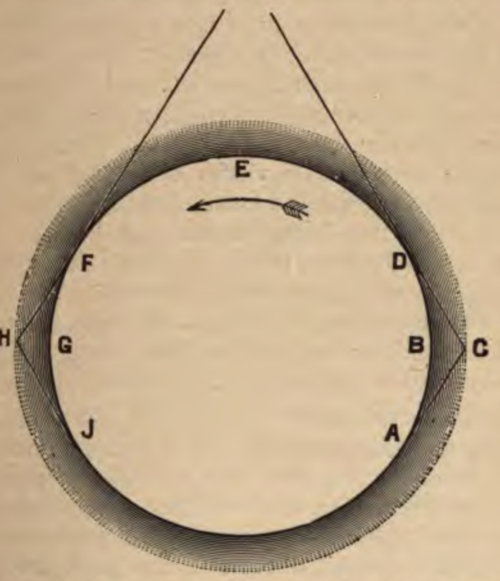


Fig. 56. Dawn and Twilight. An observer at A is in darkness, at B he receives the diffused light of the sun shining upon the atmosphere at C, at D, E, & F he receives the direct rays of the sun. Similarly, at G twilight occurs until J is reached and no part of the atmosphere is visible upon which the sun is shining.

horizon during June, in this month it is light all night. This phenomenon is caused by the reflection and scattering of the light of the sun by clouds and particles in the upper regions of the earth's atmosphere. Its duration therefore depends upon the height of the atmosphere and the angle at which the sun's rays cut it. At the equator the sun's rays cut through the atmosphere at the shortest path. In higher latitudes, however, they strike it obliquely, hence the duration of twilight is greater. From the phenomena of dawn and twilight astronomers find that the atmosphere extends about 45 miles, but luminous meteors and shooting stars afford a means of proving that it exists much higher in a very rarefied form. A shooting star or meteor is a particle of matter drawn into the earth from outer space. In space it may be dark, but as it rushes into our atmosphere a brake is put upon it and it melts away in a luminous streak. Determinations of the height at which shooting stars begin to be luminous assign a height of about 200 miles to the atmosphere, but there cannot be a definite limit to it.

All substances in nature are divided into two classes—**Elements and Compounds.** From pure gold nothing but gold can be obtained; pure mercury contains nothing but mercury; so these and 68 other substances are called elements. If, however, we take some water and, using proper conditions, pass an electric current through it, two gases are obtained called oxygen and hydrogen, in the proportion of twice the volume of the latter to that of the former. Under proper conditions these gases can be made to combine again and form water. Those substances, like water, which contain two or more elements are called compounds, and it is therefore evident that the vast majority of substances belong to this class. Mixtures may be made of various elements (e.g., the filings of metals may be mixed together), but since the proportion of the constituents may be varied at pleasure such mixtures are different from chemical compounds. Thus, gunpowder is a mixture of nitre, charcoal, and sulphur, but the proportion of these substances is not definite. As soon as the gunpowder is ignited, however, definite chemical compounds are formed. At one time air was regarded as an elementary substance, but now it is known to consist essentially of a mixture of two gases, **oxygen and nitrogen.** If we take a jar, such as that shewn in Fig. 57, and place it in water with a piece of lighted phosphorus under, as the phosphorus burns white clouds will be seen and the water will gradually rise in the jar, until it reaches about $\frac{1}{5}$ of its height. The phosphorus will then cease to burn, although some of it may remain unconsumed. The white clouds will gradually dissolve in the water and give it an acid taste. It is evident that the gas in the jar is not the same as it was at the commencement of the experiment. The gas that has been used up by the burning of the phosphorus is called oxygen, and the white clouds formed by the combination of the two elements is called Phosphorus Oxide (P_2O_5). The colourless gas remaining in the jar is called nitrogen; it is incapable of supporting combustion, and an animal forced to breathe it would die in a few minutes.

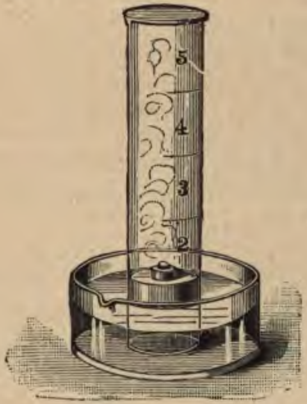


Fig. 57. The burning of Phosphorus in a jar of Air.

In addition to these two gases, other bodies are always present in minute proportions, the most important being **carbonic acid gas or carbon dioxide and water vapour.** If we neglect the amount of water vapour, which we shall see later on is variable in amount, the proportion of these gases in 100 volumes of air is:—

Oxygen	20·96	per cent.
Nitrogen	79·00	,,
Carbon dioxide	·04	,,
	100·00	

This proportion is practically the same all over the earth.

When a fire burns the carbon of the coal combines with the oxygen of the air to form carbon dioxide gas; we have in fact:—

$$C + O_2 = CO_2.$$

Carbon and Oxygen form Carbon Dioxide.

Similarly, coal contains a gas called hydrogen, which combines with oxygen and forms water-vapour, thus:—

$$H_2 + O = H_2O.$$

Hydrogen and Oxygen form Water.

These reactions take place when all fires, lamps or gas jets are alight, hence there is a continual tendency to diminish the amount of oxygen in the air and to leave nitrogen, carbon dioxide and water vapour. But it is manifest that if the oxygen be subtracted from the air, combustion will be stopped. This is the reason that a candle placed under a jar soon goes out; it uses up the available oxygen. Man and all the animal creation also require oxygen to live; this oxygen is slowly consumed in their bodies, and carbon dioxide and water vapour are constantly being breathed out; so there must be another effect to balance these reactions, or all the oxygen in the air would in time be used up. The vegetable creation does this to a certain extent. It is found that, under the action of sunlight, plants and trees absorb carbon dioxide, use up the carbon it contains, and give out from their leaves pure oxygen, thus assisting in the balance of nature. The amount of carbon dioxide present in air therefore determines whether it is fit to breathe or not. The average amount is about 0·03 per cent., that is, about 3 parts in 10,000, and air containing more than 6 per cent. of the gas should not be breathed.

A beam of sunlight shows that innumerable solid particles exist in the air; these particles are mainly grains of dust, but disease germs are often mingled with them.

We have used the term water-vapour and have stated that it is present in the atmosphere, although invisible, hence water-vapour is not steam, for steam is visible; we may, however, call it invisible steam.

After a shower of rain the wet pavements begin to dry and the water disappears; if a saucer of water be left for a little time the liquid entirely disappears; clothes are put out to dry, that is, the water in them disappears. What has become of it? It is an unalterable law of nature that nothing can be lost, so the water must exist somewhere else, and we are led to conclude that it exists in the atmosphere as invisible vapour. That this is the case is easily proved. Everyone has noticed moisture trickling down shop windows, and that an ice-cold piece of glass or metal when brought into a room becomes covered in a little time with a film of moisture, and it is evident that the moisture must have come from the air. Sulphuric acid, or oil of vitriol as it is commonly called, if left open to the air gains considerably in weight and in bulk and gets proportionally weaker; this is because it has the property of absorbing water. All these examples prove that water exists in the air as an invisible vapour. The process by which liquids are changed into the state of vapour is called **evaporation,** and the converse process, of vapour passing into the liquid state, is **condensation.** Liquids may be vaporised, that is, evaporated slowly as in the above examples, or quickly by boiling. In both cases, whether we leave a glass of water to disappear slowly or boil it away, the end is the same. Both evaporation and condensation are constantly going on all over the earth, hence the amount of vapour actually present is constantly changing. We have noted that the water disappears from the pavements because of evaporation; in a similar manner snow may be observed to disappear without a thaw, and a piece of ice, even during a hard frost, gradually loses weight owing to its evaporation. Evaporation is therefore going on at all times, but the amount is dependent upon two or three circumstances. In the first place it depends upon the size of the exposed surface, and therefore takes place most extensively on the surface of the seas and oceans. Secondly, the amount of vapour formed depends upon temperature; the hotter the air the more vapour can it take up and hold, hence a greater amount of evaporation takes place in the tropical regions, where the sun's heat is most felt, and a towel dries quickest when held to the fire. Thirdly, the amount of evaporation depends upon the quantity of the same vapour in the surrounding atmosphere, for it is manifest that if the atmosphere be full of water-vapour no more evaporation of water can go on; when this is the case the air is said to be **saturated** in the same sense that a sponge is said to be saturated when its pores are full of water. A corollary which follows from this circumstance is, that the amount of evaporation depends upon the renewal of the atmosphere, for such a renewal means merely the bringing up of unsaturated air; this explains why clothes dry quickest on windy days, when the air surrounding it is being constantly removed; if the air be still it soon becomes saturated with moisture, and evaporation ceases.

A drop of spirit evaporating from one's hand feels cold; in summer wet cloths are wrapped round bottles of wine to keep the wine cool, and in hot countries water is often kept in porous earthenware vessels for the same purpose. These facts prove that evaporation cools those bodies in the vicinity where it is going on—the more rapid the evaporation the greater is the cooling effect. The reason that cooling accompanies evaporation is found in the following :—When a solid turns into a liquid or a liquid into vapour a definite amount of heat becomes *latent* or hidden. This heat is absolutely necessary before the change of state can occur, and is obtained from any available source; in the first of the above cases it was obtained from the hand; in the case of the wet cloths surrounding bottles of wine it was obtained from the wine, and so the wine was cooled.

Evaporation, that is, the production of vapour, takes place at the free surface of a liquid; when a liquid boils, however, vapour is being formed in the mass itself. We have noted that air may become saturated with water-vapour and that the amount of such water that it can sustain in the form of vapour increases with the temperature. A cubic foot of air at 80° Fahrenheit will hold about twice as much water-vapour as a cubic foot at a temperature of 60°, hence, if air saturated at the higher temperature be cooled to the lower, half its vapour would be given up in the form of water—the water-vapour would be condensed. This fact explains why water is deposited upon cold substances brought into a warm room, and is illustrated by the following experiment. Take a glass flask and put some water in it, fit a cork with a bit of glass tube through it to the neck and boil the water by means of a spirit lamp; no steam will be seen inside the flask but only at a little distance from the end of the tube. Similarly, if we could look inside a kettle when the water in it is boiling we should not see any steam, and we know that it only becomes visible at a short distance from the spout. It is evident then that water-vapour is invisible whether it be formed by slow or rapid evaporation. When, however, the hot water-vapour comes in contact with the cool air outside the flask or kettle, steam is formed because the cold air cannot hold so much water-vapour as hot air. Steam is therefore condensed water-vapour.

In the winter a cloud of mist is seen to issue from our mouths; here again we have an example of the condensation of invisible water vapour. The steam cloud from a locomotive similarly consists of minute drops of water cooled by the surrounding air.

In spring and autumn the grass, leaves of plants and trees, stones and other objects are often seen to be covered with drops of water which we call dew. **The formation of dew** is exactly similar to the formation of moisture on a tumbler of ice-cold water brought into a warm room; these drops of water do not come from the stars as was once thought, nor do they come out of the objects themselves; they are formed by the condensation of the water-vapour of our atmosphere. In the day the earth is heated by the sun's rays; towards sunset, however, the amount of heat received by the earth from the sun is less than the amount it throws off or radiates; as the surface of the earth becomes cooled, the air in contact with it is cooled also, and from what we have previously said it is evident that if the air is cooled below a certain point drops of water will be deposited upon the cool surface for the same reason that drops of water formed upon the ice-cold glass of water. Sometimes the air has to be cooled down below the freezing point of water before this precipitation point is reached; when this is the case, the moisture is deposited at once in the solid form, and **hoar frost or white rime** is formed instead of dew. It should be observed that hoar frost is not frozen dew, but water deposited in the solid state, and can therefore only be formed when the temperature is below freezing.

Several causes influence the production of dew. Some bodies cool quicker than others, hence dew is first deposited on such

None is formed on polished metallic surfaces left out of doors, because polished metals have a very small radiating power. Grass cools about twice as fast as ordinary garden soil, hence it becomes covered with dew much quicker than the soil. Another important cause influencing the production of dew is the state of the sky; on cloudy nights the heat radiated by the earth is reflected back by the clouds, so that the land cannot cool very much; on clear, cloudless nights, however, radiation can go on rapidly, and bodies on the earth's surface therefore become chilled.

Winds also influence the amount of dew deposited, for if there is much wind the air does not remain long enough in contact with the cooling bodies on the earth to become cooled to a sufficient degree to deposit its water vapour.

A **mist** is often seen hanging over rivers and sheets of water in the evening. The reason of this is that the sun's rays fall upon the water and land during the day and raise their temperature; in the evening, however, when the sun has set, the land loses its heat quicker than the water, consequently it and the air in contact with it becomes cooled below the temperature of the water. A cold current is thus set up from the land to the water. But cold air cannot contain so much water vapour, bulk for bulk, as warm air, hence when the warm water vapour over the lake or river is chilled by the colder air from the land coming in contact with it, and water vapour is deposited as mist or fog. A mist is looked upon as a rather more condensed fog, that is, a fog passing into fine rain, hence a mist feels somewhat wetter than a fog. Fogs are frequently caused by the mixing together of masses of air at different temperatures. The cause of the fogs which always hover over the banks of Newfoundland is that the warm moist air brought by the Gulf Stream mixes with the cold air brought by the currents of the Arctic seas through Davis Strait.

Fogs are also produced when a current of warm moist air passes over a cool surface such as an ice-floe.

The reason that fogs are generally so thick and opaque is that each particle of water contains a minute nucleus of soot or some other solid matter; indeed, it has been shown that it is impossible for a fog to form without such nuclei, and it is owing to their existence that London fogs are so opaque.

Mists may often be seen hanging over tops of hills and mountains; this is because when warm air strikes against the side and is forced upwards its temperature falls and it can no longer hold so much water vapour as before. The only difference between a mist and a cloud is one of position—a mist rests on the ground; a cloud is a mist hanging in the air. One may see wreaths of cloud on mountain sides and summits, yet on standing in these clouds only masses of mist are visible. Clouds may therefore be produced by the mixture of two currents of air having different temperatures, by radiation from the mass of air to the cold sky, by the neighbourhood of cold surfaces—for example, mountain tops—or by the cooling effect of expansion when a mass of air ascends into a region of diminished pressure. Should the cooling effect still go on, the fine particles of water run together to form drops which fall to the earth as rain.

The heights of clouds vary considerably, the average being from one to two miles; it is manifest, however, that the lightest clouds are the highest and the heaviest are the lowest. If the cloud is at a great height above the earth when the rain drops begin to fall, the drops will be large because they unite together as they fall; if the cloud is low down a fine mist falls, because there has not been so good an opportunity to form large drops. At a certain height above the surface of the earth—probably about 10 miles—the temperature is below the freezing point of water, hence any water vapour that gets into such regions is frozen and a fleecy cloud of fine ice needles is formed. The large halos that are sometimes seen around the sun and moon are caused by the action of these particles upon the light of our luminaries.

To determine the amount of rainfall an instrument called a rain-gauge is used. The instrument in its simplest form consists of a funnel to catch the rain and a bottle to receive it. The amount caught is measured at a certain hour every day. If this be done through several years and the amount of rain expressed in inches, we may get the mean annual rainfall of a place. In all cases when referring to the amount of rainfall we shall give it in inches, thus, if the area of the funnel of a rain-gauge be two square feet and a gallon of water be collected, this is equivalent to a layer of water one inch thick spread over two square feet, and we therefore say the rainfall on a certain day was one inch. The weight of an inch of rain covering a square mile is 60,000 tons, that is, an inch of rain gives 100 tons of water per acre; about London, however, a fall of rain exceeding an inch in twenty-four hours is comparatively rare.

The **Mean Annual Rainfall** of a place is the number of inches of rain that has fallen for a certain period divided by the number of years of observation.

The same causes that influence the formation of clouds must also influence the amount of rainfall, since rain only represents another stage in the condensation of water vapour. The amount of evaporation that takes place is greatest at the equator, and therefore one would expect that there the average annual rainfall would also be the greatest, and, generally speaking, this is the case, the fall being greatest where the weather is hottest, decreasing as we recede from the equator and approach the poles. It seems probable that in nearly all parts of the globe situated reasonably near the coast the rainfall is almost equal to the evaporation; sometimes one exceeds the other, but this seems to be the general result for the whole year. The number of rainy days, however, are often fewest where the fall of rain is greatest.

Let us consider what happens in the torrid zone, where there is almost constant precipitation in heavy showers. Evaporation is abundantly going on, warm moist air is continually rising in the atmosphere, and it has been calculated that the temperature of the ascending air is lowered about 1° Fahrenheit for every 182 feet; therefore as the warm moist air rises it soon reaches a point in the atmosphere where it has to give up some of its moisture, and this moisture is precipitated as rain; indeed, the rainfall between the tropics is so heavy and frequent that this belt on the earth's surface is known as the **zone of constant precipitation.**

An examination of any rainfall map makes it apparent that all the continents have wet coasts to the westward. This is because they are more mountainous to the westward; for, when a strong wind meets a mountain it is forced up the side and elevated into a colder region, its vapour being precipitated by the cold due to elevation and by the expansion due to diminished pressure. Observations show that the rainfall on mountains from 4,000 to 10,000 feet high is more than double that at neighbouring places near the sea level, the mountains acting as condensers. Other **conditions favourable to rainfall** are:—Proximity to the ocean, especially when the prevailing wind comes from the ocean, hence the condensation of water-vapour into rain upon the land is greatest near the coast line. Capes and headlands projecting considerably into the ocean generally show a rainfall greater than interior stations only a few miles distant. The following are **conditions unfavourable to rainfall:** Fresh winds blowing in a nearly uniform direction throughout the year, such as prevail within a portion of the system of trade winds, especially in mid ocean. Some observations made on Ascension Island during two years showed that the direction of the wind was south east, or very nearly so, during the time, and the annual rainfall 2·3 and 4·3 inches respectively. This condition of things prevails over the Atlantic Ocean within the region where the trade winds blow with considerable force and are seldom interrupted. A second condition unfavourable to rainfall is a position on the leeward side of a range of mountains running in a direction nearly at right angles to that of the prevalent wind. An illustration of this principle is seen on the Malabar coast of Hindustan. On the ocean side of the range of mountains the mean annual rainfall is 250 inches, whilst on the eastern side of the range the air is very dry, and the amount of the mean annual rainfall is less than 25 inches. The dry state of Peru is owing to the fact that the high chain of the northern Andes takes out the last of the moisture which blows from the east across South America.

When there is a second range of mountains parallel and within 200 or 300 miles of the first the influence of this cause is much intensified, and the diminution is still more decided when a plain is surrounded by mountains, or nearly so. Salamanca is so situated, and the mean annual rainfall there is less than 10 inches.

Elevated plateaus have generally less rainfall than isolated peaks of an equal elevation; this is illustrated by the fact that Leb being situated on the remarkable plateau of Tibet has a mean annual rainfall of less than 3 inches. Another similar case is found in the table land (the Pumos) between two great chains of the Andes; and the fact that the average height of the Sahara is more than 1,500 feet may contribute in some degree to the smallness of the rainfall.

Other conditions unfavourable to rainfall are remoteness from the ocean measured in the direction from which the prevalent wind proceeds, and areas of high barometric pressure.

In Great Britain the amount of rain with a falling barometer is twice that with a rising barometer; but on advancing eastward this ratio rapidly diminishes, and in Central Europe the precipitation is greater when the barometer is rising than when it is falling.

With rainfall we connect storms. The Hon. Ralph Abercromby, writing in 1875, said, 'There are two classes of storms in this country: in the one the barometer rises, in the other it falls. In the case in which it rises, the sequence of weather is somewhat as follows:—After the sky has become overcast, the wind hushed to an ominous silence, and the clouds seem to have lost their motion, the barometer begins to rise suddenly. In the middle of this rise sudden heavy rain begins. After a few minutes the rain, with or without thunder or wind, becomes a little less heavy, and the barometer sometimes falls a little. The rain then continues to the end of the squall, and as it stops the barometer returns to its original level. In Great Britain the rise rarely exceeds 0·11 inch, or lasts more than two hours. These rises are always super-added to a more general rise or fall of the barometer, due either to a cyclone or to one of the small secondaries which are formed on the side of one. During some rises the wind remains unchanged, with others there is a more or less complete rotation of the wind. In all cases the disturbance seems to be confined to the lower strata of the atmosphere.'

We have seen that when water becomes vaporised a certain definite quantity of heat becomes hidden or latent; conversely, when water vapour is transformed into the liquid state, the same definite amount of heat is liberated, and, therefore, rainfall must have a considerable effect in warming the air, and in conveying heat to higher latitudes. It has been calculated that one gallon of rain gives out latent heat sufficient to melt 75 lbs. of ice, or to melt 45 lbs. of cast iron, and every inch of rainfall represents a quantity of heat capable of melting a layer of ice upwards of eight inches in thickness. Dr. Haughton in his Physical Geography records that the mean annual rainfall on the West Coast of Ireland is 45 inches, and the mean latitude 52° 30′ N. The amount of direct solar heat received annually is sufficient to melt 61 feet of ice, whilst the amount represented by rainfall would melt 30 feet of ice. But it should be clearly understood that the heat of condensation is transferred to the cold current, which causes the condensation of the clouds high up in the atmosphere, and does not have an appreciable effect upon the temperature of the surface on which the rain falls.

The white fleecy clouds that are sometimes seen in the higher regions of our atmosphere doubtless consist of frozen particles of water vapour. These **ice crystals** are of a regular geometrical form called hexagonal or six-sided. If a snowflake formed in calm air be examined under a microscope, it will be seen to be a beautiful pattern. The flake is really built up with minute crystals of ice, but, however complicated the form may appear, a careful examination would show that all the needles strike off at an angle of 60° (Fig. 58). When these crystals are packed close together ice is formed, but their structure is not then visible.

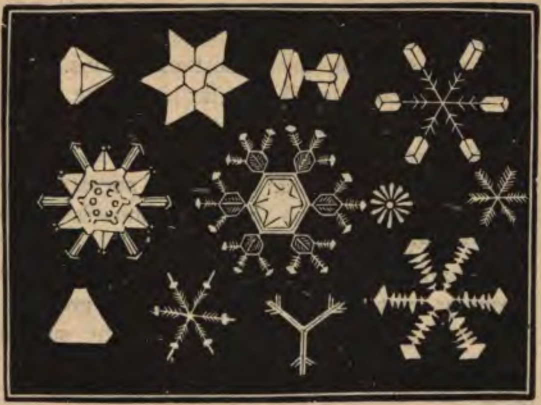


Fig. 58. Ice Crystals.

The large flakes of snow that are especially seen during warmish weather are formed by the agglomeration of smaller flakes; this process can only take place when the air is damp. In very dry weather the snow falls in the condition of small pellets, and if the air is intensely cold, that is, much below the freezing point of water, any snow which may then fall appears in the form of minute flakes like a white powder.

Snow is never seen at places in the torrid zone, for if it be formed in the higher and colder regions of the atmosphere it would be melted before reaching the surface of the earth; hence it is never seen in places where the average temperature is much above freezing point, so that snow never falls over by far the larger part of the globe.

It is evident that snow may be formed at some height all over the globe, although its occurrence at sea level is confined to certain parts. At the equator, where the temperature is high, it is only seen on the loftiest mountains. The high peaks of the Andes stretch so far into the upper and colder regions of the atmosphere that they are perpetually covered with snow. At the poles the surface of the ground is similarly covered to sea-level. But this perpetual covering of a surface with snow means that more snow is formed than can be melted by the heat of the sun. Hence there is a certain height above sea level all over the globe where snow can perpetually exist, and the height will be greatest where the sun's heat is greatest, and least where the sun's heat is least. An imaginary line joining the heights above which occurs perpetual snow is called the **snow-line or limit of perpetual snow.** Below the line, the heat of the sun is sufficient to melt all the snow that falls. The following is the height of the snow-line at various places :—

At the Equator	16,000 feet
Quito	15,800 ,,
On the high peaks of Mexico ...	14,800 ,,
In Spain	11,200 ,,
On the Alps ...	from 8,000—9,000 ,,
Dovre Fjeld Mountains (Norway)	4,000 ,,
North Cape	2,000 ,,
Spitzbergen	almost at sea level

It will be seen that there is a gradual descent of the snow-line as the latitude increases.

When snow falls through a layer of warm air and is somewhat melted we get a fall of what is called **sleet**.

Hail is much denser than snow, being more like ice. It may fall in hard or soft pellets and is known as hard or soft hail. The pellets may vary in size from a small pea to a pigeon's egg, large hailstones being formed by the freezing together of small hailstones during descent to the earth's surface. On cutting a hailstone into two and examining it under a microscope a speck of dust or some such matter will be made visible, and it is probable that no hailstone could be formed without such a nucleus. Hailstones also present the appearance of being built up and not the appearance that would follow from the sudden freezing of drops of water (Fig. 59); hence the impression that hail is rain frozen as it falls is entirely erroneous; but although this gradual formation is beyond doubt, no sufficient theory has been propounded to account for the fact that they must remain suspended in the atmosphere before they fall.

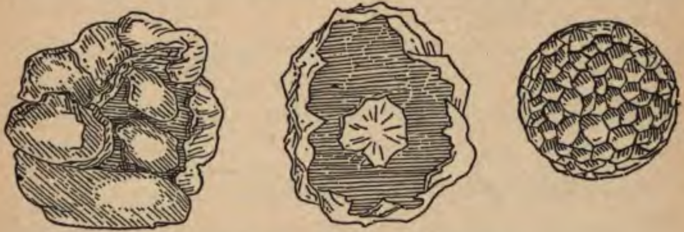


Fig. 59. Sections of Hail.

It is evident from what we have said that agencies are continually at work carrying the dust and other particles from the atmosphere to the earth; a fall of rain clears the air considerably, dissolves gases such as ammonia from it, and carries them down to the earth to fertilize the soil and to feed plants. Of course the amount of matter suspended in the air differs at different places and is greatest near smoky towns; in the country the rain and other falls are much purer and far less contaminated; indeed, in Mourzouk, south of Tripoli, rain is depended upon for drinking purposes and is the only water obtainable.

GENERAL SUMMARY OF CHAPTER IX.

The weight of air is determined:—

(1.) By weighing a globe empty and full of air and observing the increase of weight.
(2.) By means of the barometer.

The Atmosphere consists essentially of a mixture of oxygen, nitrogen and carbon dioxide in the following proportions by volume:—

Oxygen	20·96	per cent.
Nitrogen	79·00	,,
Carbon Dioxide	·04	,,
	100·00	

The amount of aqueous vapour varies considerably.

How the composition of the atmosphere is kept nearly constant. Animals require oxygen to live and expire carbon dioxide; plants require carbon dioxide to live and give out oxygen.

The Height of the Atmosphere has been determined by—

(1.) Observations of dawn and twilight.
(2.) Observations of shooting stars.

An element is a body that cannot be split up by analysis **a compound** contains two or more elements, and can be analysed.

Water-vapour is invisible.—Steam is not water-vapour, but water in a state of very minute subdivision.

Evaporation is the process by which a liquid is changed into a gas; **condensation** is the process by which a gas is turned into a liquid. Both are constantly going on all over the earth.

Latent Heat.—When a solid turns into a liquid, *e.g.*, ice into water, or a liquid into vapour, *e.g.*, water into water-vapour, a certain amount of heat becomes hidden or latent; conversely, when a vapour passes into a liquid state or a liquid into a solid this latent heat is given up.

In ebullition or boiling vapour is produced within the liquid; in evaporation the vapour is produced at the free surface.

Dew is moisture deposited upon cold surfaces from the air surrounding them.

Hoar-frost is not frozen dew but moisture deposited in a solid form from the atmosphere.

Mist and Fogs.—A mist is produced when water-vapour becomes condensed into minute hollow drops. A fog is very similar to a mist, but the drops of water composing it are hardly so large.

A Cloud is nothing more than fog or mist formed high in the atmosphere.

Rain is produced by the running together of the water particles forming a cloud so as to form larger drops, which fall to the ground by the force of gravity.

Rainfall is measured by means of a rain-gauge and is expressed as the thickness in inches of the fall if it were spread evenly over the surface of the land where it occurred.

The Mean Annual Rainfall of any place is determined by measuring the rainfall for several years and finding the average; this differs at different localities and is dependent upon the latitude, direction of prevailing winds, proximity to the ocean, and the conformation of the surrounding country.

Snow consists of crystals of ice joined together into hexagonal or six-rayed stars; a number of crystals joined together form a snow-flake.

The Snow-Line, or limit of perpetual snow, is the name given to the height above which the summer heat is not sufficient to melt all the snow that falls, and below which the summer heat is sufficient to do so.

Sleet is snow that has been somewhat melted by falling through a warm layer of air—a mixture of half-melted snow and rain.

Hail consists of hard pellets of snow or ice. It is not formed by the passage of rain through a cold layer of air, but gradually, in a manner not well understood.

CHAPTER X.

THE MOVEMENTS OF THE ATMOSPHERE.

CONSIDER our globe at rest, isolated in space and covered uniformly with water; it can be well understood that in such a case there would be no tendency for the water to move from one point to another. In the same way, if the earth were at rest and surrounded with an atmosphere of uniform density, and if the sun did not exist, there would be no movement of the air, and winds would be unknown; but we know that the air is subject to disturbance and indeed seems never still. Light breezes are constantly moving the leaves of the trees or heavy winds roughly shaking the trunks. What is the cause of the movement and what are the laws that govern it, are questions to be answered in this chapter.

Everyone is familiar with the saying that 'water always finds its own level,' and understands by it that the surface of a fluid is horizontal. If water be disturbed so that one portion becomes at a higher level than the remainder, motion is set up until it is all at the same level again, that is, any disturbance of the equilibrium of the water, or indeed of any fluid, causes an oscillatory motion to be set up until equilibrium is restored. Gases, as well as liquids, obey the laws of fluid motion, hence when the air is at a higher pressure on the earth's surface at one place than at another, there is a tendency for the upper layers to slide off until equality of pressure is restored.

In the last chapter the barometer, an instrument by which the atmospheric pressure is measured, was described; and since it is differences of atmospheric pressure that regulate the motion of winds, by studying the readings of barometers at different times and at various places we may learn something about atmospheric motion.

It may have been noticed that when describing in the last chapter how the weight of air is determined, we said that the value given only held good when the temperature was that of freezing water. If the experiment had been made at the temperature of boiling water the cubic foot of air would have been found to weigh about $\frac{9}{10}$ oz. instead of $1\frac{1}{4}$ oz., hence hot air is lighter than cold air. Again, moist air is lighter, bulk for bulk, than dry air. A cubic foot of dry air at a temperature of 50° F. weighs nearly 547 grains, whilst a cubic foot of water-vapour at the same temperature only weighs a little over 4 grains. The humidity or quantity of water-vapour that air can hold is different at different temperatures—the hotter the air the more vapour can it hold. Now, the more water-vapour the air at any place contains the less is the atmospheric pressure at that place, and therefore the lower is the barometer. Winds are caused by differences of atmospheric pressure, and therefore any circumstance that is the cause of a change of temperature of the air, or affects the amount of moisture it contains, causes a wind to be set up.

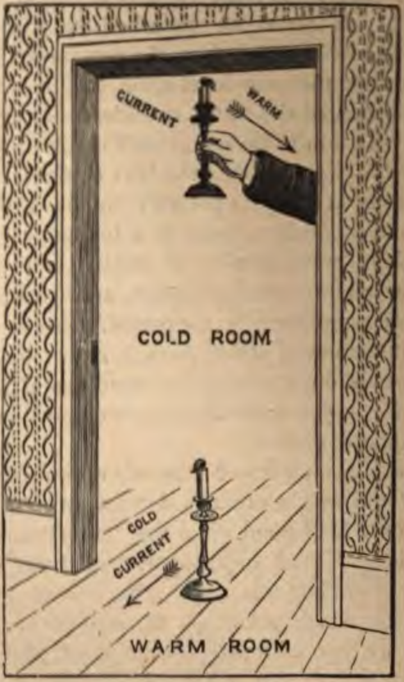


Fig. 60. Currents caused by difference of Temperature.

When a fire burns it is heating the air near it, and the heated air ascends up the chimney because it is specifically lighter; cold air then rushes in from all sides to take the place of the heated air—thus so long as the fire burns a circulation is kept up, currents of air from the outside forcing themselves through the walls and crevices of the room to the source of heat and then being sent up the chimney. If the chimney be stopped up or anything done to prevent this free circulation the fire goes out; if anything be done to concentrate the current upon the burning coals—such as the common practice of holding a newspaper across the fire-grate—the fire burns brighter.

It would be expected from what we have said that under any circumstances, in a room or in the open air, the hotter air will occur at a higher level than the colder, and that so long as this difference in density exists currents will be set up from the cold air to the hot. That such is the case is capable of easy demonstration. Hold a candle first at the top and then at the bottom of the open door of a warm room (Fig. 60); when at the top the flame will be blown outwards, while at the bottom it will be blown inwards, and by means of a thermometer it may be shown that the current going outwards is warmer than the inward current. We thus see that by the action of heat a circulation of air is kept up, and in this fact lies the cause of many phenomena.

At the seaside during the day a breeze blows in from the water and is called a **sea-breeze**; after sunset, however, the wind veers round and blows from the land to the sea—this is called a **land-breeze.** Now some substances take more heat than others to raise them to a given temperature, and therefore these substances take longer to cool than others. Water takes more heat to raise its temperature one degree than the same weight of any substance, hence water takes much longer to lose its heat than anything else. When the sun is shining upon the earth during the day it is known by common experience that the land soon becomes hot; the water, however, does not become so warm, hence the air resting on the land in the day is warmer than that resting on the water and so a sea-breeze is set up; a light current flows from the colder and therefore denser air to the warmer and lighter. In the evening the sun's rays are withdrawn, the land loses its heat quicker than the water, and the air resting upon it becomes cooler than that resting on the water—so a land-breeze is set up, the current again flowing from the colder and heavier air to the warmer and lighter (Fig. 61), the tendency always being for the air to flow and keep in movement until it is all at the same temperature.

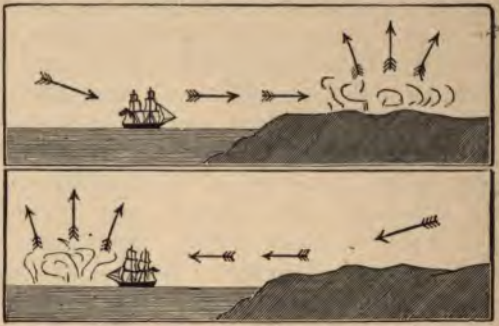


Fig. 61. Sea and Land Breezes.

A connection exists between the motion of such currents as those described and atmospheric pressure. At the equator where the air is hottest there is a constant sliding off towards the poles of the upper layers of air, and air is continually rising up as it gets heated; this upward motion of the air lowers the pressure of the atmosphere, or we may conversely say, that where the barometric pressure is low there are currents ascending in the atmosphere. On the other hand, where there are descending currents the atmospheric pressure is increased and the barometer reads high.

Extending this reasoning to the case of the earth taken as a whole, we have the fact that the air is hottest over the torrid zone; ascending currents are therefore set up, and other currents rush along the earth's surface to take the place of the ascending air. Where the ascending currents occur the barometer will read lower than at higher latitudes, and, as a matter of fact, at the equator the average barometric height at the level of the sea during our winter is 29·88 inches, whereas in latitude about 40° N. it has been found to be 30·20 inches.

It is evident therefore that in the northern and in the southern hemisphere there is a constant tendency for two currents to flow from the direction of the poles along the earth's surface to the equator, and if the earth were at rest there would always be a north wind in the northern hemisphere and a south wind in the southern hemisphere. But the earth is in rotation, the air at the poles has no motion of rotation, whilst the air at the equator is whirling round with the earth at the rate of 1,000 miles an hour—hence as the current flows from the poles to the equator it is constantly dropping behind, and instead of a wind blowing direct from the north pole we get a wind from the north-east, whilst in the southern hemisphere the wind blows from the south-east. These winds are constant and are called **north-east and south-east trade-winds**, because the early navigators depended upon them for commercial purposes. They are chiefly felt between the tropics and the equator.

Besides the cold lower current flowing from high latitudes to the equator there is the upper warm current flowing from the equator to high latitudes. These return currents are gradually cooled in their journey poleward, and observations show that they reach the surface in about the thirtieth parallel of latitude. Here again, if only the change of temperature and therefore difference of pressure gave direction to the return currents, they would flow due north and due south; but we have a combination of motions, the air has a higher velocity at the equator than in higher latitudes, consequently the currents flowing poleward are constantly getting ahead, and since the earth rotates from west to east they flow from the equator in a south-west direction in our hemisphere and in a north-west direction in the southern hemisphere. Such winds are called the '**Anti-trades.**' In our hemisphere their effect is nc striking because of the influence of the land, which causes irregular motion of the currents. In the southern hemisphere, however, where there is little land to get heated and cause local currents, the anti-trades blow with considerable constancy and force; and between latitude 40° and 50° in the Pacific and South Indian Oceans these winds are known as the **Brave West Winds**, and the latitudes in which they blow as the '**Roaring Forties.**'

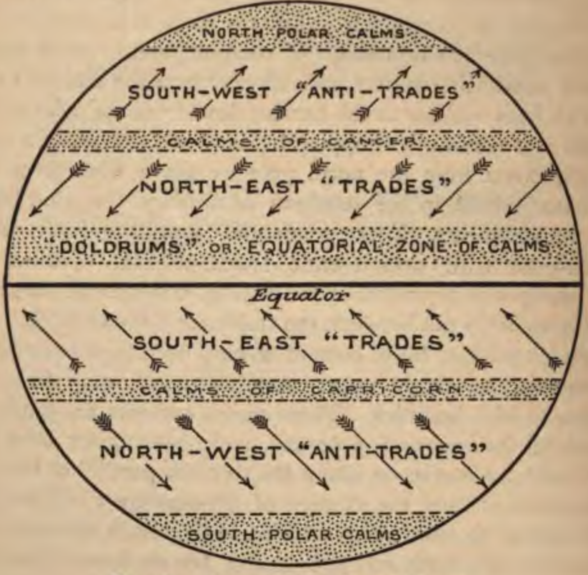


Fig. 62. Constant Winds and Calms.

It is well known that the prevalent wind in Britain and the west of Europe is south-west, and the foregoing furnishes the reason for this. In towns where such winds are prevalent the 'west end' is always the best end, and the reason is obviously because they reach that end fresh and uncontaminated with the dirt and disease that are suspended over the towns, and blow these impurities to the east end. The general direction of the trade and anti-trade winds described is shown in Fig. 62.

We pointed out in a previous chapter that the sun is only directly over the equator twice a year, that it journeys north and reaches the tropic of Cancer in July, then turns south and reaches the tropic of Capricorn in January, hence the trade winds do not constantly blow to and from the equator but to or from some zone north or south of it according to the position of the sun.

The irregular conformation of the land surface of the earth affects considerably the constancy of the trade and anti-trade winds. In January the belt of heated air lies nearly along the equator with little but sea under it, the consequence being that the trade winds are then more distinctly felt than when the sun is further north of the equator and the belt of heated air extends over Asia and the northern part of Africa. In the Atlantic and Pacific Oceans, where there is little land in the track of the winds, they are most regular. In the Indian Ocean the mass of land north of the equator and forming the continent of Asia prevents the north-east trade wind from blowing at all, and the south-east trade wind alone is constant.

We thus see that a circulation of air is continually going on, the region where the trade winds blow extends to about 25° north and south of the equator, and it is manifest that where the north-east and the south-east winds meet we shall have a belt of calms—they will neutralise each other. Such a belt, about five degrees in breadth and characterised by low atmospheric pressure, runs nearly parallel to the equator, and is called the '**Doldrums**' or the zone of calms; within it the heat is suffocating and sometimes intense calm prevails, at other times heavy rains and violent thunderstorms occur. If the earth were uniformly covered with water the belt of calms would always lie directly under the sun because that would be the line of greatest heat; the greater amount of land in the northern hemisphere, however, causes the line of greatest heat to lie north of the equator and therefore the belt of calms also. In the Atlantic Ocean the belt of calms lies entirely to the north, but as the sun journeys north and south of the equator the belt moves with it; near the end of our summer it reaches its most northerly limit in eleven degrees north latitude, and towards the end of our winter its lower limit, in one degree north latitude, is reached.

There are other belts of calm, called respectively the **Calms of Cancer and Capricorn**; these are caused by the crossing of the polar currents forming the trade winds, and the return currents or anti-trades. Unlike the equatorial belt of calms, the calms of Cancer and Capricorn are characterised by high atmospheric pressure and generally bright weather. The trade and anti-trade winds are called constant winds, the currents that prevail in the belts of calm are variable.

Some winds have a marked seasonal character, and it is to these we would now direct attention. Such winds are called **Monsoons,** which is the Malay signification for a season of the year. They are most perfectly developed in the Indian Ocean, where, as we have before noted, no north-east trade wind blows. During winter in India, that is, from November to April, the north-east monsoon prevails. The sun is then south of the equator—the temperature of South Africa is thus higher than that of Asia—the ascending currents cause the barometer to fall and currents of air therefore blow along the earth from Asia to South Africa. They leave Asia as dry winds; as they cross the ocean, however, some moisture is taken up to be deposited on the south-east coast of Africa. The summer wind in India blows from May to October, and has a south-west direction, which it will be observed is in an exactly opposite direction to the course of the trade-winds. The sun is then north of the equator and Central Asia gets very hot, the result being that air colder than that lying on the plains of Asia is forced towards the centre of rarefaction. This cold air comes from the Indian Ocean and carries moisture, which is deposited in India and the east of Asia; indeed, the rainfall is so excessive during the summer monsoon in some regions that it is called the wet monsoon. The country east of the Western Ghats receives comparatively little rain, for two reasons. (1) The north-east monsoon blows as we have seen mostly over the land and is therefore a dry wind, and (2) most of the moisture in the south-west monsoon is precipitated in the passage of the wind over the western slopes of the Ghats. On the coast of China the winter wind is a north-west monsoon, and the summer wind a south-east monsoon; the latter is looked forward to by the Chinese farmer to water his land, and both are utilised by navigators of the Indian Ocean and China Sea in the same way as the trade winds.

The change of the monsoons is marked by considerable atmospheric disturbance. Rain falls in almost continuous streams and causes the rivers to overflow and spread over the level plains. The lightnings flash and the accompanying thunders roar with terrible grandeur for hours together, and create an uproar not easily forgotten.

Weak monsoons also blow in North America and even in Europe; they have the same cause, viz., the alteration in the temperature of these continents according to the position of the sun. As summer occurs the land and the air overlying it gets hotter than the surrounding water, consequently winds blow towards the centres of these continents from all directions, and the direction of the monsoon or periodic wind will depend upon the geographical position of any place in its track; in the winter, however, the land gets cool, air rushes out from the centre and dry winds having a reversed direction prevail. The winds blow in upon all desert regions in the summer and flow out from them in the winter in both the northern and the southern hemisphere.

There are certain **local winds** having special names. The '**Mistral**' is a wind that blows over Southern France. It comes from the high land of Central and Eastern France and therefore is a cold wind; the moisture of the air in the lower regions is condensed by the cold, the result being that torrents of rain generally accompanies this wind. In Africa and Arabia the **Simoon** occurs—a dry, hot and suffocating wind rushing across deserts and whirling up clouds of sand that may completely bury whole caravans. The **Harmattan** is the name given to a similar wind that blows at certain times of the year from the heated Sahara to the coast of Guinea. The **Sirocco** is a hot wind originating in the same manner, but containing a great deal of moisture taken from the Mediterranean. It blows in a south-east direction towards Sicily and Italy and causes extreme languor. In Spain it is called the **Solano** and sometimes contains fine dust, carried across the narrow part of the Mediterranean from the deserts of Africa.

The motion of wind on a small scale may be seen on dusty roads. A whirlwind is set up and travels as a whole down the road carrying clouds of dust with it. It is well known that if water be made to whirl round inside the vessel containing it, the centre of the whirl is depressed below the level of the edges. In the same way the centre of any such whirl set up in our atmosphere must be a depression, and therefore, when the centre of a whirlwind on a vast scale passes over any place, the barometer will fall because the atmospheric pressure is less; indeed, in the whole region of the whirl the atmospheric pressure will be less than just outside. Such movements of the air are called **cyclones** and all storms are of this character.

If a cyclone in the northern hemisphere could be viewed from above the atmosphere the whirl would be in the opposite direction to the hands of a watch; a cyclone in the southern hemisphere whirls in the same direction as watch hands (Fig. 63). In addition to this cyclonic movement the whole body of air moves, so that when a storm passes over a country first the wind blows furiously in one direction, then there is a short lull as the centre of the storm passes, and then the wind blows from an opposite direction. Since there is a gradual lowering of the barometer from just outside a storm area to its centre, if it is found that there is a difference of one or two inches in the barometric heights, say at Paris and Bristol, a heavy gale may be expected—the greater the difference of atmospheric pressure the more violent will be the wind. Every morning observers at all the principal towns in England and on the Continent telegraph the height of their barometer and the direction of the wind to a central office; a map is then taken and lines drawn upon it connecting those places where the atmospheric pressure is the same—these lines are called *isobars*, and are more or less circular curves described round a centre where the barometer stands lowest. The curves may embrace an area thirty miles in diameter or a thousand miles, and by daily observations at a regular hour, such as those above described, the whole cyclone may be mapped out and, the direction of its movement being known, storm warnings may be sent to places in its track.

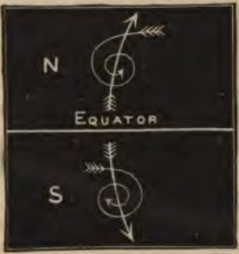


Fig. 63. Motions of Cyclones in the Northern and Southern Hemispheres.

Now, there is a connection between the direction of the wind and atmospheric pressure, and it is expressed in what is known as **Buys-Ballot's law**, which may be stated thus :—'It
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you stand with your back to the wind in the northern hemisphere the barometer will be lower on your left hand than on your right. If you stand with your back to the wind in the southern hemisphere the barometer will be lower on your right hand than on your left.'

Hence, if the direction of the wind be observed, the distribution of atmospheric pressure may be deduced, or conversely, if the distribution of atmospheric pressure be known, the direction of the wind may be found, and it is by the utilisation of this law that storm warnings are rendered possible.

The average rate of movement of a storm is from fifteen to thirty miles an hour; the whirl of the air that forms the wind, however, may have a much greater velocity. The following table of velocities of winds and the consequent pressures is taken from Scott's 'Meteorology':—

	Miles per hour.	Lbs. per sq. ft., approximately.
Calm	3	·08
Light Air	8	·6
Light Breeze	13	1·5
Gentle Breeze	18	2·9
Moderate Breeze	23	4·7
Fresh Breeze	28	6·9
Strong Breeze	34	10·2
Moderate Gale	40	14·2
Fresh Gale	48	20·3
Strong Gale	56	27·8
Whole Gale	65	37·5
Storm	75	49·9
Hurricane...	90	71·8

In some cases the gusts of wind may have a velocity of 120 miles an hour, but rarely more.

The direction in which a cyclone travels is generally that of the prevailing wind. Thus a cyclone from the tropics moves in a westward direction towards the pole, that is, with the trade winds. In Europe, where the prevailing wind is westerly, storms generally come from the westward, so that they pass over France, Portugal and Great Britain, and often lose their fury in Russia. Hence it is rarely that a storm reaches the east coast of England without warning having been received.

Fig. 64. A Tornado.

It is easy to see that if water be in the track of a whirling mass of air a **water-spout** may be formed and made to move with it; if dust be in the track of the spiral, a simoon or dust spout may be the result. Various names have been given to cyclonic movements of the air in different localities. In the West Indies they are known as **hurricanes**, and in the China Seas and the Bay of Bengal, **typhoons**. What is known as a **tornado** is merely a whirlwind or cyclone having a small area. The violence of these whirlwinds is well known, and the track of one, although rarely more than a quarter of a mile wide, is like that of an advancing army—a path of destruction and devastation. One half of a house may be cut down and the other half remain uninjured, whilst heavy carts and trees may be transported some distance by the movement of the whirling spiral of air. A tornado does not last long, however, but exhausts itself after passing over about twenty or thirty miles (Fig. 64).

Torrents of rain are usually associated with storms. The reason for this is, that as the air is whirled upwards it must expand, by expansion it becomes cooled, water-vapour is thus condensed and rain may follow.

We have seen that a cyclone is an area of low pressure. An ANTI-CYCLONE is an area of high barometric pressure, the centre of an anti-cyclone showing the highest barometer reading. The lower air in a cyclone is made to rise and flow in a spiral course into the central depression; in an anti-cyclone the state of things is reversed, air flows out from the centre of highest pressure and is caused to descend as it does so.

The weather that accompanies an anti-cyclone is very different from that accompanying a cyclone. As the air in an anti-cyclone is forced to descend it becomes compressed and gets heated; it could thus take up much more moisture and hence always comes to us as a dry air; the sky is also generally free from clouds, although sometimes fog occurs at the centre of the system.

The motion of the wind in an anti-cyclone in the northern hemisphere is in the direction of the hands of a watch, being contrary to the motion in a cyclone; it is also generally more or less stationary and does not move rapidly from west to east as a cyclone does in our latitudes.

GENERAL SUMMARY OF CHAPTER X.

Winds are caused by differences of atmospheric pressure and always blow from regions of high atmospheric pressure to regions where the pressure is lower.

Differences of Atmospheric Pressure may be caused by the unequal heating of the air or by its unequal humidity.

A Barometer reads low:—

(1) When there is an upward current, for this causes reduction of pressure, and occurs when the lower strata of air gets hot.

(2) When the air is moist.

A Barometer reads high:—

(1) When there is a downward current, for this causes increase of pressure, and occurs when the lower strata of air gets very cold.

(2) When the air is dry.

All winds are deflected from a straight course; in the northern hemisphere the deflection is to the right hand, in the southern hemisphere to the left hand.

The Constant Winds are:—

The North-East Trades ...	... 6° N. to 35° N.
The South-East Trades ...	... 1° S. to 30° S.
The South-West Anti-Trades	... 35° N. to 65° N.
The North-West Anti-Trades	... 30° S. to 65° S.

The Belts of Calm are:—

(1) The Equatorial Calms, varying in position with the declination of the sun and having a mean position 6° N.—characterised by low pressure.

(2) The Calms of Cancer about 35° N. and of Capricorn about 30° S.—characterised by high pressure.

(3) The Polar Calms around each pole—characterised by low pressure.

Periodical Winds—*e.g.*, **Monsoons**—blow at definite periods and in certain directions, and are caused by the unequal temperature of land and water at different seasons of the year or times of the day.

Variable or Occasional Winds—*e.g.*, **Cyclones**—blow at any time and in any direction, and are due to local or temporary circumstances causing water or land surfaces to become unequally heated.

Cyclones are Occasional Winds.—They are most violent in the torrid zone, where the heat and moisture are greatest. They are characterised by (1) low pressure, (2) the winds blow towards the centre, (3) the direction of the whirl is in the opposite direction to the hands of a watch in the northern hemisphere, and with watch hands in the southern hemisphere, (4) wet weather.

Hurricane and typhoon are local names for cyclones.

An Anti-cyclone is the region of relatively high pressure that occurs between two cyclones, and differs in almost every respect from a cyclone.

CHAPTER XI.

CONFIGURATION OF THE LAND.

The crust of the earth is understood to mean that thickness of the whole mass which can be investigated and studied. The structure and constitution of the crust may be determined by observations in quarries and mines, by borings, and by the examination of the substances brought to the surface by springs, and during volcanic eruptions. Such examinations enable us to learn something of the character of the crust down to about 15 miles below sea-level. And since the highest mountain (Mt. Everest) is about five and a half miles high we may say that our knowledge of the earth's crust is limited to a thickness of twenty miles.

One half the weight of the rocks that make up the earth's crust consists of oxygen. Silicon is the next substance in order of abundance and makes up one quarter of the earth's crust. The other elements which, together with oxygen and silicon, make up 99·9 per cent. of terrestrial matter are aluminium, magnesium, calcium, potassium, sodium, iron, and *carbon*. Few elements are found in a free state; oxygen a silicon always occurring in chemical combination with other elements.

The following table shows the relative quantities of these and other elements present in the earth's crust, assuming it to have a thickness of ten miles below sea-level:—

Oxygen	50·0
Silicon	25·0
Aluminium, Magnesium, Calcium, Potassium, Sodium, Iron	22·7
Carbon, Sulphur Hydrogen, Chlorine Nitrogen	2·3
	100·0

There is little doubt that all the chemical elements are present in solution in ocean waters, and also in the earth's crust, although they may occur in very small quantities.

A MINERAL is an inorganic substance, all the parts of which exactly resemble each other and have a definite chemical composition. The most abundant mineral is Felspar, which contains silicon, aluminium, potassium, and oxygen; then follows quartz, which consists of silicon and oxygen.

A mountain may be defined as land rising considerably above the general level; a mountain-range as a ridge of high land running through a country, a mountain-chain or mountain system as a number of mountain-ranges running parallel or having their bases in contact, and a mountain-group as several ranges more or less connected with each other, or a number of peaks.

Mountain-ranges usually run in one general direction through a country. Thus in Europe and Asia the chief ranges run nearly east and west; in North and South America the axis of high land and mountain-ranges runs north and south; Africa is encircled with mountain-ranges, the main highland regions lying along the east coast. Australia has also a region of elevation similar to Africa along the east coast, and from it rise the peaks of New Guinea and the Australian Alps. It is interesting to observe that the regions of high land and mountain-ranges occur on the west side of America and on the east and south-east sides of Africa and Australia; thus the Atlantic Ocean receives the drainage of both the Old and the New World. It should also be noticed that in the cases of Africa and Australia elevated regions occur on the side of the continent which has a general curve outwards, whilst the lower lands follow the inward curve.

Isolated mountains of a conical form rising abruptly from a plain or from the sea are generally volcanoes. Etna, Vesuvius, the Peak of Teneriffe, and the Friendly Islands in the Pacific, being examples of this kind. The American geologist, Dana, defines this formation in the following words:—

'A **volcano** is a mountain or hill, more or less conical in shape, which has a nearly central cavity at the top called a **crater**, and which discharges at times melted rock called **lava**, and also vapours or gases. The lava either flows down this or that side of the mountain in streams, or is projected into the air to fall around the vent, or lava-source in fragments. The cooled fragments from a **projectile** discharge are called volcanic **cinders**, but the finer part, often, volcanic **ashes**; if not cooled on the descent, they are **drops** or **driblets**.'

The student must guard himself against the popular notion that volcanoes give out fire when in action, for what appears to be flames is simply the reflection of the red hot lava in the pipe upon the steam cloud which is produced. This cloud of steam is also often erroneously said to be smoke. Again, the cinders referred to in the definition are not unconsumed coal but melted fragments of rock, much like the slag of an iron furnace, whilst the volcanic ash or dust is produced by the rubbing together of the ejected materials and from the bubbling lava.

There are more than 300 active volcanoes on the globe, and most of them are situated on islands, on the edges of continents and near the sea. Thus 200 active volcanoes occur on the islands and near the coast of the Pacific and Indian Oceans, and there is a continuous chain of them running along the Andes of South America, Central America, and the rocky mountains past the Aleutian Islands down to Japan, and reaching a maximum of activity in Formosa, the Philippine Islands, and the Malay Archipelago. At this point the line of volcanic activity divides into two branches; one turns north-westward through Java and Sumatra—regions of frequent and large volcanic eruptions—along the eastern side of the Bay of Bengal; the other turns south-eastward through New Guinea and the New Hebrides into New Zealand, and across the Pacific to South America by the Friendly, Society, and Easter Islands. Thus the Pacific is encircled with a vast ring of active volcanoes. A similar, though not so distinct line, may also be traced around the Atlantic (Fig. 65).

The fact that these lines follow very nearly the direction of great lines of elevated land is very important, inasmuch as it affords evidence that such lines of relief or fracture in the earth's crust are often composed of melted rock. Even in those mountain-ranges where no active volcanoes occur, investigations sometimes show that they once existed but are now dormant.

The explosion of a torpedo deep down in the sea causes a system of concentric waves to appear at the surface. Similarly a disturbance in the interior of the earth—it may be the contraction, or the falling in, of rocks, or it may be the sudden generation of steam as a mass of water gets heated—causes a wave system to be set up on the surface of the land, and such movements are called **earthquakes** (Fig. 66). By observing the direction of the breaches made in houses, the angle at which the earth-wave reached the surface, and the position of the *seismic vertical*, it has been found that the origin of the shock may have a depth of from 20 to 30 miles. The occurrence of an earthquake is marked by rumbling noises both in the earth and in the atmosphere; the ground rises and falls and some-

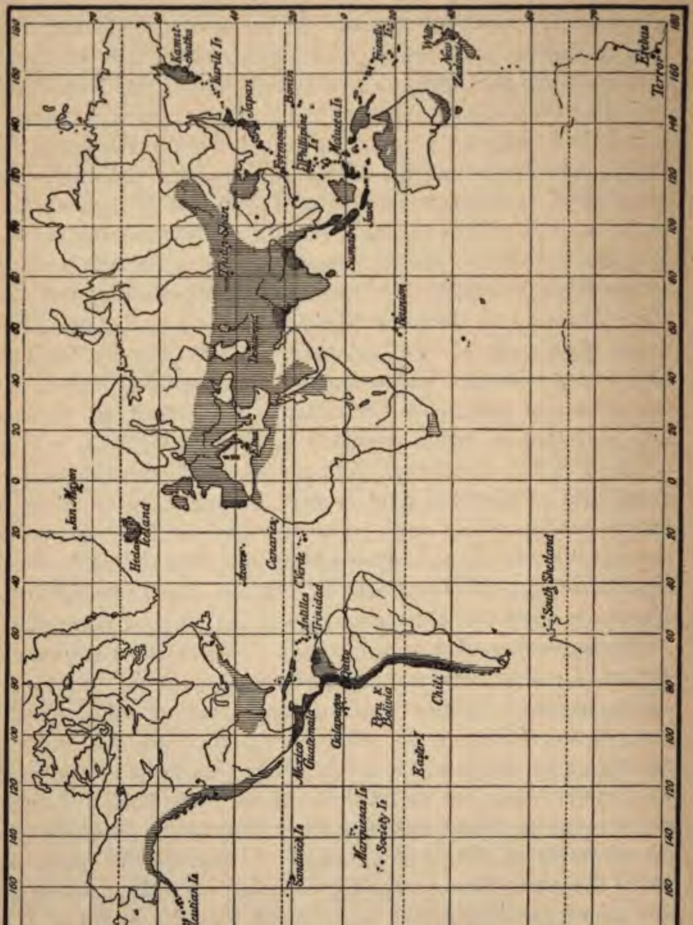


Fig. 65. Distribution of Volcanoes and Earthquakes. The former are indicated by dots, the latter by shading.

times opens; whilst houses and trees are rocked to and fro, and sometimes shaken down in a few moments. The distribution of earthquakes follows almost the same lines as that of volcanic eruptions, the Andes of South America and the Japanese Islands being great centres of both phenomena, whilst a well-defined line passes through further India and across Asia to Southern Europe.

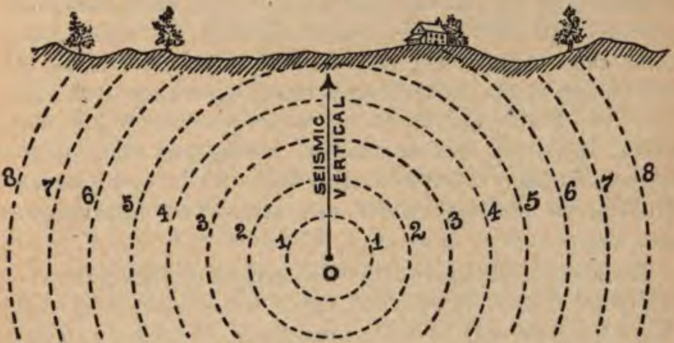


Fig. 66. Production of Earth Waves by a disturbance at O. The position of the Seismic Vertical and the direction in which waves strike the surface enables the depth of O to be calculated.

An earthquake may not only cause the ground to rise and fall temporarily but may effect a permanent elevation or subsidence of land. The coasts of Chili and New Zealand have been suddenly raised in this manner several times, and a region covered with trees in the Mississippi valley subsided during an earthquake that occurred at the beginning of this century. There are also **slow movements of upheaval and subsidence** of the land continually going on. Numerous old sea beaches containing marine shells are found on the west coast of South America up to a height of 1,300 feet above sea level, and their existence indicates in a conclusive manner, that a gradual upheaval has taken place. Similar raised beaches with marine shells have been observed in Siberia and Spitzbergen. Another proof of upheaval is afforded by the fact that old sea-ports have been found many feet above sea level. The existence of old Greek houses beneath the water on the eastern shore of Greece, and of submerged forests near Devon and Cornwall, also testify to a slow subsidence of portions of the land surface of our globe. Similar evidence is afforded by the fact that the bases of coral reefs sometimes extend deep down in the ocean, although the reef-building corals cannot exist at a greater depth than twenty fathoms, the explanation of the circumstance being, according to the late Charles Darwin, that the rock to which the coral is fixed once existed at a depth less than twenty fathoms, at which period the coral-builders fixed themselves to it. As the rock gradually subsided the building upward went on, and the coral reef was thus always kept at sea-level.

The average elevation above sea-level of the land surface of the globe is about 2,000 feet, hence those lands which are below this level may be called **low-lands**, whilst those above it may be termed **high-lands.** An extensive and comparatively flat surface occurring in low-lands is called a **plain**, thus:—the **Great European Plain** extends over more than half the surface of Europe, being bounded by the North Sea on the west and the Ural mountains on the east. The prairies of North America and the plains of Australia are similar examples. The same term is used even when the land rises by a gradual slope from low-lands into levels much above the average, *e.g.*, the Rocky Mountains in North America rise from a land which has an elevation about 5,000 feet above sea-level, but the great plain east of them has a gradual slope downwards to land below the average level.

When a comparatively flat expanse of land rises rather abruptly above the general level in high-lands it is termed a **plateau or table-land.** There is no hard and fast distinction, however, between plains and plateaux, and land that rises in a steep slope from low-lands is often termed a plateau. The great plateau of central Asia has an average elevation of 12,000 feet. Another great plateau extends in Western North America from the Rocky Mountains in the east to the Cascade Mountains and the Sierra Nevada on the west. The average elevation of this plateau is from 4,000 to 5,000 feet at Utah. The waters from the highlands run into the relatively low lying portion of the plateau, called the 'Great Basin,' extending from the Great Salt Lake to the Sierra Nevada and, having no outlet, form a series of salt lakes.

Valleys are belts of relatively low-land between higher lands. They are met with in every region, but are most marked amongst hills, mountains, and plateaus. The land lying between two parallel mountain chains is called a **longitudinal valley**, and when a depression cuts across a mountain chain it is called a **transverse valley.**

The rain that falls on a mountain chain creates torrents of water, which flowing down the sides scoop out the transverse valleys. All such torrents flow towards longitudinal valleys and act as feeders to main streams, hence, generally speaking, a longitudinal valley has not such a great slope as a transverse one.

The valleys on the east and west slopes of the Pennine Range and those running westward from the Cotswold Hills into the Severn are examples of transverse and longitudinal valleys.

A good example of a river valley may be seen at Bristol. At one time there was a gradual slope towards the west of a plateau known as Clifton and Durdham Downs. The young Avon then flowed in a minor inequality of the surface towards the Severn on the west, and continually deepened its channel; the result being that now the Avon flows in a gorge more than two hundred feet below the level of the land on either side.

In regions where the rainfall is slight and the slope of the bed in which the torrent flows is great, a very steep gorge or

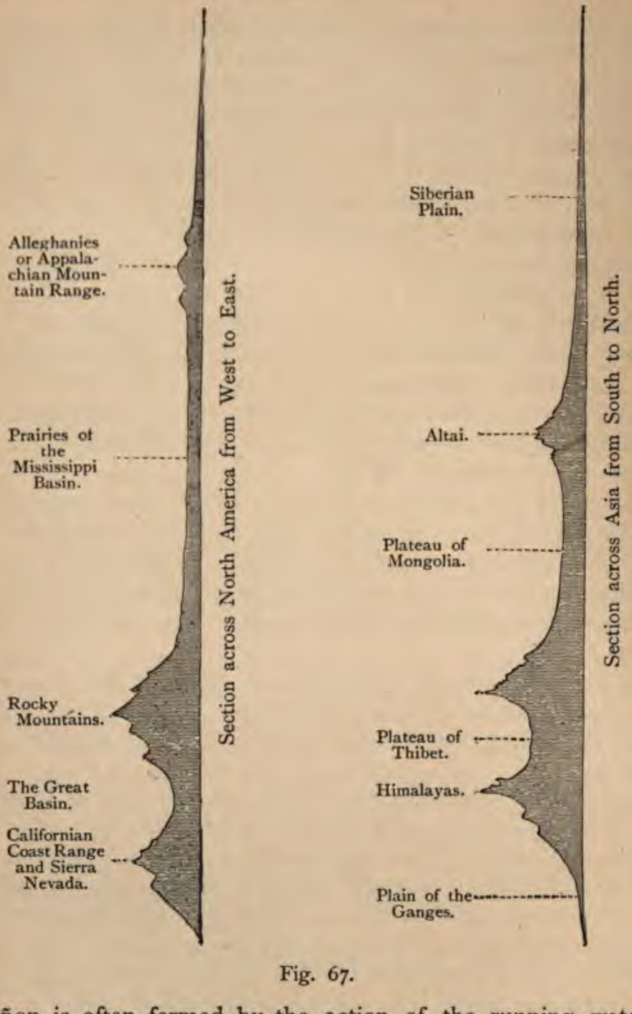

Alleghanies or Appalachian Mountain Range.
Prairies of the Mississippi Basin.
Rocky Mountains.
The Great Basin.
Californian Coast Range and Sierra Nevada.
Section across North America from West to East.
Siberian Plain.
Altai.
Plateau of Mongolia.
Plateau of Thibet.
Himalayas.
Plain of the Ganges.
Section across Asia from South to North.

Fig. 67.

cañon is often formed by the action of the running water Examples of this kind of valley are met with along the course

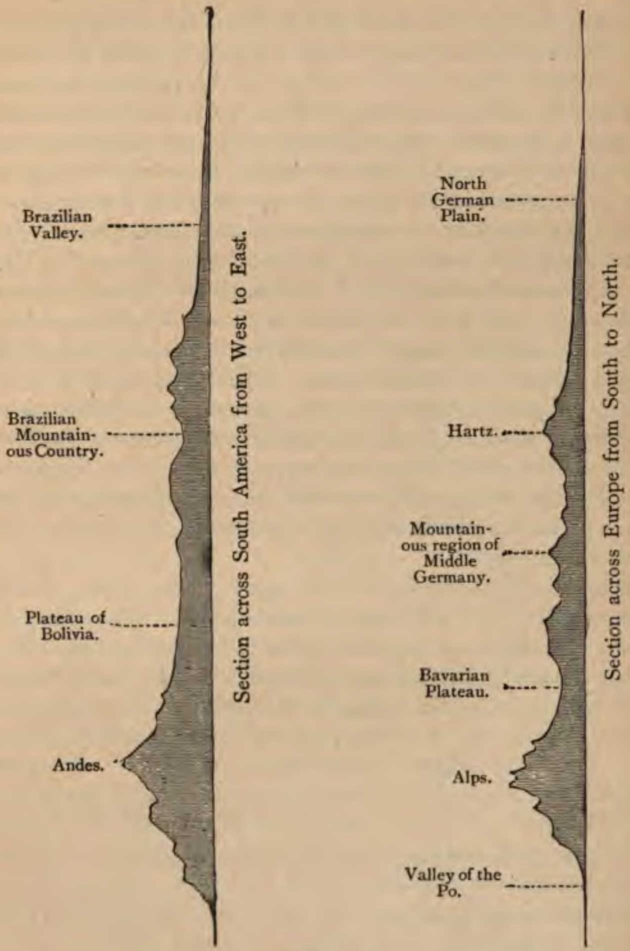

Brazilian Valley.
Brazilian Mountainous Country.
Plateau of Bolivia.
Andes.
Section across South America from West to East.
North German Plain.
Hartz.
Mountainous region of Middle Germany.
Bavarian Plateau.
Alps.
Valley of the Po.
Section across Europe from South to North.

Fig. 67.

of the Colorado and Virgin rivers, and the smaller streams which feed them. Where the rainfall is heavy such formations are impossible because the banks of the cañon get worn away, the tendency then being to make a V-shaped valley instead of the U-shaped trench.

There is evidence to show that our globe was once entirely covered with water. The land first to emerge from this covering was of course the most elevated. In a continental mass like South America, the Andes on the west coast first appeared, and if we could lay a straight edge from them to the east coast a gradual lowering of level would be observed. East of the mountains table-land occurs, then follow hills and undulating land and low plains until sea level is reached. The same sequence might be observed if sections were taken across other continents (Fig. 67). It must be manifest to the majority of people, however, that the present diversified character of the land surface of our globe could not have been the same when it was under water, nor when it arose from the water. At that time there could have been no jagged peaks or abrupt spurs of land, and observations have made it plain why they should now exist.

Everyone has seen waves dash against a sea coast. Large fragments of rock are loosened and fall into the water to be broken up and used to batter other portions; the rough fragments thus get smoothed and reduced to pebbles, and then to sand. If the coast be steep, the base of the cliff is worn away until the weight of the overhanging top causes enormous masses of rock to break off and tumble into the sea below. Frequent land-slips of this kind occur along the south coast of Devonshire and Cornwall. If some parts of a cliff are softer than others caves, channels, and creeks, are formed, and if there are portions much harder than the general mass of rock, they are left as isolated outliers, needles, or stacks, in the sea, while the coast is being worn away. The process by which rocks are broken up is termed **erosion,** the loosened material is called **debris** or **detritus,** whilst the general work of disintegration and removal is termed **denudation.**

The oxygen in the air is always combining with the constituents of rocks and forming new compounds; this of course means the breaking of the rocks. The exposed surfaces of rocks may become rusted, so to speak, and crumble away into powder, thus leaving a fresh surface for the oxygen in the atmosphere to combine with. Again, in the day the heat of the sun causes rocks to expand, whilst at night they quickly cool and the sudden contraction that is consequent upon such cooling causes the rocks to crack, whilst both effects tend to loosen particles on the surface. We have also the effect due to the freezing of the water contained in all the little cavities and crevices of rocks. As the water freezes it expands, and the force of expansion is so great that rocks containing the freezing water are broken up and pushed aside. Lastly, there is the action of carbon dioxide contained in the atmosphere and in rain. All rocks having limestone as one of their constituents are easily broken up, the rain containing carbon dioxide dissolves the limestone, and the loss of this rock causes the particles near it also to break up. '**Weathering**' and '**Sub-aerial denudation**' are the terms used to express changes in rocks such as the above described.

It is evident from the foregoing that in general the more rugged the character of a mountain the longer has it been subjected to erosion, whilst hills with rounded tops represent upheavals of more recent times.

GENERAL SUMMARY OF CHAPTER XI.

The Two Most Abundant Elements in the crust of the earth are:—

(1.) Oxygen.—A colourless gas that supports combustion and is estimated to form one-half of terrestrial matter.

(2.) Silicon.—This forms one-quarter of the earth's crust, but does not exist uncombined.

The Two Most Abundant Minerals in the crust of the earth are:—

(1.) Felspar.—This substance forms 48 per cent. of the mineral creation, and contains the four elements Silicon, Aluminium, Potassium, and Oxygen.
(2.) Quartz.—This is pure Silica ($Si\ O_2$), and forms 35 per cent. of the crust.

Rocks are classed as follows:—

(1.) Stratified, or those that occur in more or less parallel layers.
(2.) Unstratified, or those that occur in masses not having this appearance.

The General Structure of the Land Surface of our globe may be given as follows:—

(1.) Mountain peaks, ranges, and systems.
(2.) Plateaus or table lands.
(3.) Minor elevations, or hills.
(4.) Undulating land.
(5.) Longitudinal and transverse valleys.
(6.) Plains.

An Active Volcano has:—

(1.) Its vapour, or gaseous discharges.
(2.) Its lava discharges.
(3.) Its projectile discharges.

The Crust of the Earth is subject to movement, viz:—

(1.) Sudden trembling, or convulsions of the ground called earthquakes.
(2.) Slow upheavals, or subsidence.

Some Proofs of Upheaval are:—

(1.) Raised sea-beaches.
(2.) Docks and piers of old ports found above sea level.

Some Proofs of Subsidence:—

(1.) Disappearance of human erections.
(2.) Submerged forests.
(3.) Coral islands.

Valleys are formed by the action of rivers, and are longitudinal and transverse according to whether they run parallel with or cut across mountain systems.

Erosion is the operation by which rocks are broken up into material called *debris.*

CHAPTER XII.

SPRINGS AND RIVERS.

We have considered the moisture in the air and the various forms in which it is precipitated to the earth. It has also been shown that a considerable amount of the precipitation returns to the atmosphere again by evaporation. The amount thus disposed of has been estimated as about one-third, another third is absorbed by the land in which the fall occurs, and the remainder flows off the land at once into the rivers.

We know from general observation that some substances will hold water whilst others cannot hold it so well. When a garden is watered the soil absorbs the liquid and it quickly disappears. If, however, we were watering a layer of clay we know that the water would not be so readily soaked up. Now substances that let moisture pass through them are said to be *permeable;* substances that prevent the passage of water are called *impermeable.* Chalk, sandstone, loose sand, and gravel are examples of the first kind, whilst clay and slate are examples of the second class of rocks.

Everyone is familiar with the springs that are met with at the side of many hills; and many persons have, when walking in dry weather, visited the spot where they once saw a spring bursting forth only to find it dried up, whilst in wet weather it flows copiously. It is evident, therefore, that springs are dependent in some way upon rainfall, and the way is easy to understand. Rain falls, and some of it sinks into the earth and comes at last to an impermeable rock, it may be, clay; through this rock the water cannot pass, and if we consider the layer or stratum to lie in a slope as shown in Fig. 68, the water will flow down the slope of impermeable rock and reach the surface at a point where the permeable stratum meets the impermeable one. From the explanation it is manifest why during a drought the spring must dry up, and during wet weather its flow should be increased.

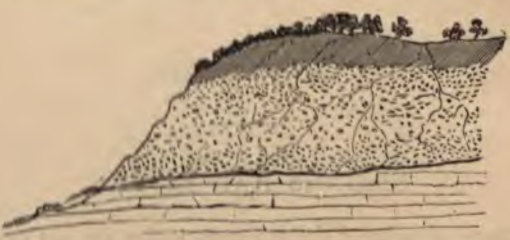


Fig. 68. A Surface Spring.

It is manifest that variations in the temperature of the air only affect the soil and the rocks under it to a certain depth, which depth, however, must be very different in summer from what it is in winter and very different in different parts of the earth. Beyond this depth of from 50 to 100 feet, the temperature is the same all the year round, and in our part of the globe is nearly equal to the mean annual temperature. At still greater depths the temperature is higher on account of the heated interior of the earth, and increases about one degree for every 60 feet of descent.

Now it is evident that the water of a spring assumes the temperature of the rocks through which it percolates. A mere surface spring, therefore, has a much different temperature in summer and in winter. If, however, a spring sinks to a moderate depth it has an almost constant temperature, only a small variation being caused as the water rises to the surface. Hence, by determining the temperature of springs, we may get a good approximation of the temperature of the rocks in which they occur; that is, we may get to know something of the temperature of the earth's interior.

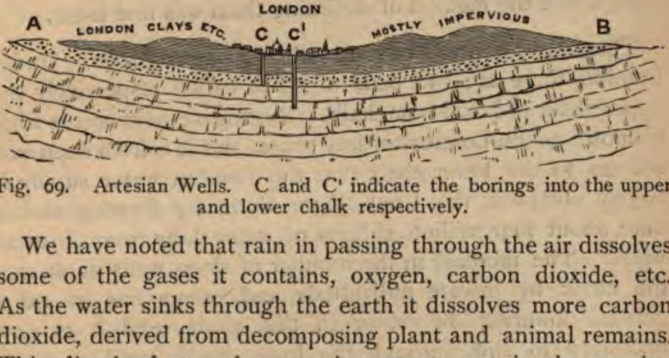


Fig. 69. Artesian Wells. C and C' indicate the borings into the upper and lower chalk respectively.

We have noted that rain in passing through the air dissolves some of the gases it contains, oxygen, carbon dioxide, etc. As the water sinks through the earth it dissolves more carbon dioxide, derived from decomposing plant and animal remains. This dissolved gas plays an important part in the wearing down of rocks. Many rocks are dissolved by water containing it in solution, which would otherwise be unaffected, and its presence in spring water is the cause of the delightful sparkle.

In the French province of Artois, some years ago, it was found that, by boring to a considerable depth in the ground, water rose out of the bore hole with great force after a certain depth had been reached. To understand the cause of this, consider two basin-shaped impermeable layers separated by a permeable one as shown in Fig. 69. When rocks lie as shown in the figure, they are said to have outcrops at A and B. The water that falls on the high ground at A and B will sink through the permeable stratum and, following the natural slope of the ground, will finally collect in the hollow of the basin, and be under hydrostatic pressure due to the height of the water in the permeable strata. If now a hole be made at C the water, in trying to regain its level, will spurt out with a force dependent upon the level of the water and the point where the hole is made. The depth of the bore of course varies in different localities, and the water often comes from a distance of 60 or 70 miles. Such supplies of water are called **Artesian wells**, from the name of the town where the method of obtaining them was first used.

There are hundreds of such wells now in existence. Under London there are two beds of chalk called respectively the upper chalk and the lower chalk. Resting on these occurs what is known as the London tertiary strata, and it is from deep well borings to the lower chalk that the London water supply is largely obtained, the Kent Water Company deriving at one time about four million gallons of water daily from Artesian wells. The increase in the number of deep wells sunk into the chalk by private individuals and others has caused a gradual lowering of water in this strata, and it is now necessary to sink through the lower chalk until a water-bearing stratum is reached below it.

The well at the Reform Club, Pall Mall, was sunk 120 feet before the chalk was reached, and then the chalk was penetrated to a depth of 200 feet; whilst the fountains in Trafalgar Square are fed by a boring which has a depth of 250 feet to the chalk and a depth of 135 feet in the chalk. These depths are not, however, nearly so great as some in other localities, for at Grenelle one has been sunk to a depth of 1800 feet, and delivers 650 gallons of water every minute.

Strictly speaking, all springs are mineral springs, for they all contain solid matter, the nature of which depends upon the constitution of the rocks through which a spring passes. **Sulphur springs,** as that of Harrogate, contain the disagreeable gas called sulphuretted hydrogen in solution; springs containing a compound of iron dissolved in them are termed **ferruginous or chalybeate springs;** those containing much dissolved carbonate of lime are called **calcareous,** whilst brine springs contain a large proportion of common salt. Other substances, such as sulphate of magnesium, etc., are dissolved in spring water. It is the quantity of carbonates and sulphates of lime and magnesium that determines whether water is hard or soft. Water, however, may be temporarily or permanently hard, and the difference between the two is that a temporarily hard water may be made soft by boiling whilst there is no practicable method for transforming a permanently hard water into soft water.

The cause of this is as follows. Water containing carbon dioxide in solution has the power of dissolving limestone or carbonate of lime, and such water is hard; if, however, it be boiled, the carbon dioxide is driven off and the water can no longer hold the limestone, so it is deposited and forms the fur of kettles and the incrustation of boilers. No amount of boiling, however, will cause the sulphates to be deposited, for they remain dissolved whether water contains carbon dioxide or not; hence water having sulphates in solution is permanently hard.

The greater the pressure to which water is subjected, the more carbon dioxide gas can it hold. This fact is well illustrated by the opening of a bottle of aerated water. When the cork or stopper is withdrawn, the pressure upon the liquid is lessened, and the liquid, often nothing more than sweetened water, can no longer hold so much carbon dioxide gas in solution, so bubbles of it fizz out into the air. Applying the same principle to the earth, we find that at great depths the water contains more carbon dioxide in solution than water at the surface.

Now one of the powers affecting the dissolving of mineral matters by water is the amount of dissolved gases it contains; hence when spring water, after percolating through the earth, reaches an underground cavern, it contains more carbon dioxide and more dissolved material than it can retain: the consequence is some of the gas escapes, and since the water cannot then hold as much limestone as at first, some is deposited as a white film. Similar films may be formed by all other falling drops of water containing lime in solution, so that by the deposit of one film upon another a stalk or icicle of stone is formed. Such growths are called **stalactites**. When the water hanging from the end of the stalactite is let go it falls to the ground and a further evaporation takes place, the result being a growth commences on the floor, the white solid pillar formed being called a **stalagmite**. These growths

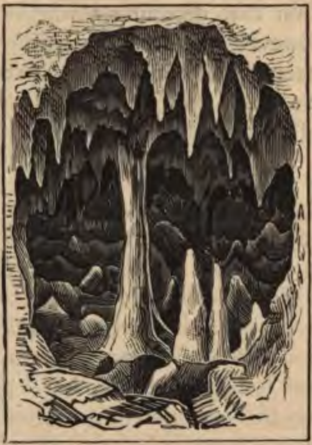


Fig. 70. Stalactites and Stalagmites.

may go on until the two pillars meet to form one continuous column of stone (Fig. 70). The production of stalactites may be seen on the inner side of many arches or on the vaulted roof in a cellar, the carbonate of lime in these cases being derived from the mortar.

The **petrifying springs** which are popularly supposed to turn any object placed in them into stone are simply springs containing a considerable amount of dissolved carbonates. When a spring so constituted issues into the air, a lot of carbonate of lime is deposited on every object over which it passes, owing to a loss of carbonic acid gas by the water; an object such as a bird's nest, or a basket, left in the spray of such a spring soon gets coated with an incrustation of carbonate of lime and is said to be petrified or turned into stone, although in reality it is only covered with a thin film.

If the map of any country be inspected, numerous small rills and brooks will be seen in the higher regions; lower down these small brooks coalesce, become larger, less numerous, broader, and deeper as they flow. At last, only a few of these running masses of water remain; a river has been formed which finally discharges itself into the sea.

All these moving bodies of water flowing in a definite direction on the earth's surface are called **streams,** being rills or rivulets, brooks or rivers, according to their size. It is usual, however, to speak of a stream as the flow of water formed by the union of several springs, when they increase in size they are called rivers.

All water above sea level has a tendency to flow down into the sea because of the action of gravity, hence the source or beginning of a stream must be at the highest level. One point is looked upon as the source of a stream by the inhabitants of a country, and is generally accepted as such. This point may be a spring, as in the case of the Danube; or a mass of melting snow or ice, as in the case of the Rhone; a marsh, a swamp, or a lake, like those from which the St.

Lawrence and Amazon rise. It is, however. difficult to definitely say what is the source of a stream, for every drop of water that trickles down the side of a mountain aids to form it.

The use of rain is to water the land, the use of rivers is to drain it. The little rill of water rushing down the mountain slope soon reaches a part where the inclination is not so great; it travels slower as its path gets more level, streams run into it from either side and thus increase its size; the flow goes on, the number of small streams is diminished, and a mighty river is finally produced which empties itself into the sea, or, it may be, into a lake or a much larger river.

When two streams meet as above described the smaller is said to be an **affluent or tributary** of the larger, and the junction of the two is called their **confluence** The place where a stream joins or flows into a larger stream, or into a lake or sea, is called its **mouth.** When the mouth of a river is very wide and reached by the sea tide it is called an **estuary**.

The course along which a typical river flows may be divided into three parts—the torrential part, where the slope is steepest and the waters rush rapidly down; the valley part, where the speed of the water is not so great; and the plain part, where the river receives few tributaries, but moves slowly towards the sea.

It is evident that the formation of the land has a considerable influence upon the motion of a river. When the stream trickling down the mountain side meets with a rocky boulder it is turned aside in its course; it takes the path that offers the least amount of resistance to the flow. The stream winds sometimes to one side and sometimes to another, is turned aside by ridges and heights, and follows always the line of least resistance. But this path is seldom the shortest.

A river with all its tributaries form together a stream system, and we may look upon a river as draining that part of a country containing the streams that feed it. The whole land surface from which the supply is obtained is called the **river-basin**, the rain basin, drainage basin, or catchment basin. In North America nearly all the water goes to the Mississippi, and, excepting the great lakes drained by the St. Lawrence, we may almost speak of North America as being the drainage basin of the former river. The extent of a drainage basin can, of course, only be approximately known. We give, however, the area of the drainage basin of a few rivers.

Amazon	2,200,000	square miles.
Congo	1,600,000	,,
Mississippi	1,250,000	,,
Ganges	432,500	,,
Rhine	75,000	,,
Severn	8,680	,,
Thames	6,960	,,
Shannon	6,940	,,
Tay	2,230	,,

Since each river drains a certain area, lines may be drawn along the boundaries of these areas, and such lines will mark where a division takes place in the drainage of that region. Thus, a line may be drawn to join the sources of all the streams that are tributary to the Thames, and such a line of represents what is termed the **water-parting**, water-shed, ridge line, line of least slope, or simply the divide. Streams always occupy the valleys of a country, or the lines of depression. On the other hand, a water-shed is a line of elevation. It need not be a sharp ridge formed by the meeting of two slopes down which streams flow and may be an irregular line of relatively high land separating adjacent stream systems (Fig. 71).

A water-shed, in fact, behaves like the ridge on the roof of a house, dividing the waters that fall upon the roof and sending them down in different directions. Since this is the case the general direction of a river system is at right angles to the water-shed. A good example of a water-shed is afforded by the chain of the Andes running through the full length

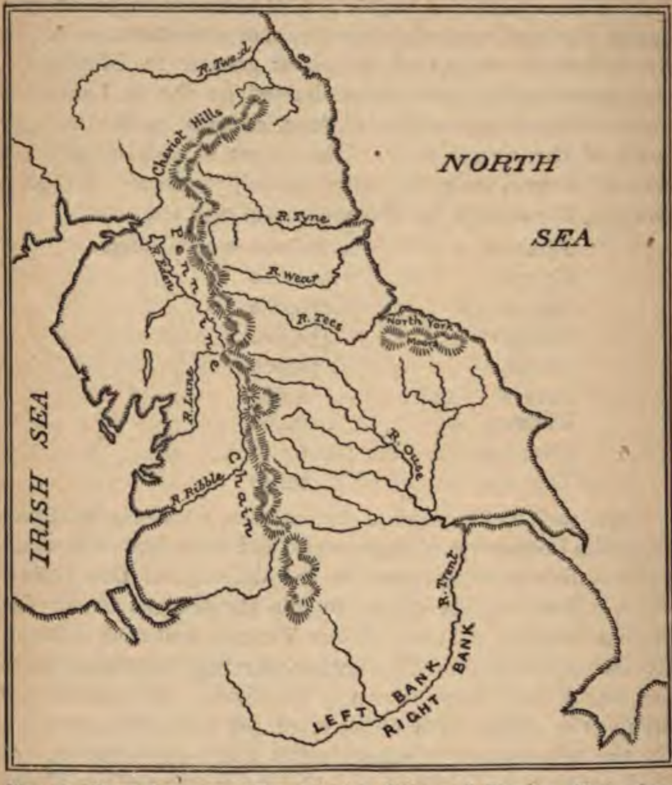


Fig. 71. River Systems. The Cheviot Hills and Pennine Chain form a water-shed from which on one side rivers run into the Irish Sea and on the other into the North Sea.

of South America, and nowhere less than a mile above sea level. This mountain chain runs north and south and hence the rivers flow east and west. But the chain of the Andes runs along the west coast of South America and is only about 70 miles distant from the Pacific, whilst it is 2000 miles from the east Atlantic coast. Consequently all the water that falls on the west side of the water-shed will quickly reach the Pacific as a few mountain torrents, whilst that which falls over the vast continent, and that precipitated by the lofty mountain chains, flows towards the east coast and gathers together as it does so, the result being that on this coast there are three of the great rivers in the world, the Orinoco, the Amazon, and the La Plata. In fact this principle, that when a water-shed runs close to one edge of a continent the larger rivers occur on the side of least slope, must always apply.

Dr. Haughton sums up the following conditions to be fulfilled by a continent for the successful manufacture of rivers:—

(1.) An abundant supply of aqueous vapour brought by the prevailing winds.

(2.) The continent should have an area sufficiently large for the rainfall to feed great rivers.

(3.) A range of mountains sufficiently high to precipitate all the aqueous vapour, at right angles to the prevailing winds, and placed on the leeward side of a continent.

It will be seen that all these conditions are fulfilled by South America.

All who have rowed on the Thames, or any such river, know that in order to go up stream when it is running fast it is best to keep to the side; if, however, it is required to go down stream at the quickest rate it is necessary to pull more in the centre, and these facts are sufficient to prove that a river moves faster at the middle that at the sides. It is also a matter of common knowledge that when a river is swollen its velocity is increased, and that the average velocity of streams differs. The average velocity of an ordinary river current is about 1½ miles an hour at low water to about 6 miles an hour at high water, and the velocity of rapid torrents never exceeds twenty miles an hour. The main cause influencing the velocity of a river is the slope of its bed or channel. If a mile could be measured along the bed of the Missouri, one extremity of the line would be found about 28 inches lower than the other; hence it may be said that since the mean fall of the Missouri is 28 inches to a mile, and there are 63,360 inches to a mile, the fall is 28 in 63,360, or about 1 in 2,263. The fall of the Volga is 3 inches to the mile, or 1 in 21,120, which is a very small proportion. If the inclination be much more than 10 inches to the mile, rapids are formed and the river is not navigable. Where the descent is very steep great waterfalls like the Niagara are formed, those of smaller size being called cascades. As a rule, the slope of a river decreases as the mouth is approached.

We have noted that the flow of rivers also varies with high and low water, that is, is dependent upon the volume of water in motion. It is easy to see why this should be so. The water at the sides and bottom of a river has its advance retarded by friction, hence the velocity at the surface is greater than the velocity at the sides and bottom of a river. When, however, a river is high or swollen, the surface is increased and is also further from the bottom where the friction is greatest, and therefore the river flows faster.

Many measurements have been made of the average water discharge of rivers, and from the data thus obtained a mean annual discharge has been calculated. The following are some of the values found, but of course they must be accepted as very rough approximations.

Amazon	520	cubic miles
Congo	420	,,
Ganges-Brahmaputra ...	290	,,
Mississippi	140	,,
Danube	40	,,
Nile	25	,,
Tay	1	,,

That the length of a river is no criterion of its volume may be seen by a comparison of the preceding with the following table.

Mississippi-Missouri	4,400	miles
Nile	4,200	„
Amazon	3,800	„
Yenisei	3,300	„
Yang-tse-Kiang	3,200	„
La Plata	2,500	„
Volga	2,100	„
Danube	1,700	„
Thames	224	„
Severn	199	„

It is evident from these tables that a long river may have a small discharge. This may be because of a loss of water in its lower course, or because it may be shallow and have fewer tributaries than a shorter stream. The Nile is one of the longest rivers in the world, and yet it has a very small discharge; indeed, the volume of this river decreases rather than increases as it approaches the sea, owing to the fact that it passes through a rainless region. It is estimated that no river discharges into the sea more than one half the rainfall that occurs in its basin. In the case of the Rhine the discharge is about one half, the mean annual discharge of the Ohio river is stated to be one fourth of the rainfall, the Mississippi about one-fifth, the Missouri about one-seventh, whilst the discharge of the Nile is only about $\frac{1}{40}$ of the rainfall.

The greater portion of the remainder of the rainfall is returned to the air again by continual evaporation from the moistened soil, and from every snow or water surface. It is evident, therefore, that the larger a river system is, the slower the motion of the river, or the drier the region through which it passes, the smaller will be the proportion of discharge to rainfall.

The fact that brooks dry up, rivers diminish in volume, springs cease during a drought, and that sudden and continuous rainfall causes rivers to become swollen and sometimes overflow their banks, proves very conclusively that all such volumes of water are very dependent upon the precipitation of moisture from the atmosphere. In those countries where regular seasons of wet and dry weather occur, the springs, brooks, and rivers periodically rise and fall. The volume of all large streams fluctuates with the season; in some streams, however, the change is much more noticeable than in others. This periodic rise and fall is well marked in the case of the Nile and Ganges. The former river shows a sensible rise at Cairo about the beginning of July, which continues until the end of September, when a maximum of from 20 to 30 feet above the June level is reached. A constant level is maintained for about a fortnight, then the level decreases; on November 10th half the maximum height is reached and at the end of November the true inundation has ceased. This rise and fall occurs with perfect regularity every year, and was a subject of much discussion with the ancients, who thought it was caused by the melting of snows. This theory is correct to a certain extent, but the true cause is that the high and rocky table land of Abyssinia is visited by heavy rains during the months of March and April; these rains create torrents of water in the numerous mountain gorges, which rush down and swell the Blue Nile. The periodicity of the rainfall thus causes the regular rise and fall of the river.

The Ganges rises from May till September, owing to the melting of snow on the Himalayas and the occurrence of the wet monsoon. Similarly, the Rhine and the Rhone, whose sources are the snows and glaciers of the Alps, increase considerably in volume during the summer and shrink during the cold and often wet months of the year.

We will now consider the work done by the streams in their movement over the surface of the earth. As rain passes through the air it absorbs small quantities of the various gases. Chief among these dissolved gases are carbon dioxide and oxygen. It has been previously noted that water containing carbon dioxide in solution is capable of dissolving chalk or any calcareous rock; hence, when rain falls, such rocks, and other rocks as well, get eaten away. Raindrops falling upon mud or sand leave impressions. The continual beating of raindrops upon rocks carries away the loose material on their surfaces and the softer rocks are affected more than harder ones; hence, we may class the action of rain upon rocks under two heads, (1) those actions which are chemical, (2) those that are mechanical. And, since rain has so great an action upon the land, it is easily understood that the action of rivers is much greater.

Rivers, streams, and brooks are constantly eating away and undermining their banks. The water dissolves certain portions of the land and thus loosens other portions, the undermining of the banks causes fragments of rock to fall, which are then broken up by the action of the water. As a river moves on it is constantly transporting the loosened particles and exposing fresh surfaces, the soil set free being carried down by the current and used for rubbing and wearing away the bed in which the water flows.

It is the suspension of solid particles that gives colour to the water of rivers, the colour being dependent upon the nature of the rocks in the course. As the solid particles are hurried down stream they get reduced to fine sand or mud and the channel is constantly getting enlarged; sometimes the suspended material is caught in eddies and whirled round so as to form what are known as pot-holes in the bed. A good example of the wearing away of the bed of a river is afforded by the Niagara Falls. It is found that the falls are gradually receding up the river, that is to say, if the position of the fall relative to the land be noted at any time and again noted a few years later, it will be found to be different. The amount of recession is said to be two feet in a year; this means that the rocks over which the water falls is being eaten away at the rate of two feet in a year. A deep trench stretches from the present position of the falls down to Queenstown, seven miles distant. From Niagara to Queenstown the land on either side of the trench gradually decreases in level. At the latter place, however, the level suddenly drops, and the limestone rocks form a cliff above a vast plain (Fig. 72); hence it would appear that the river originally fell over the cliff at Queenstown and that the erosive action of the water has brought the falls to their present position. It is easy to calculate that, at an average rate of two feet in a year, the river must have taken about 185,000 years to excavate the ravine that occurs between the falls and Queenstown. This kind of excavation must go on in every case where water falls over a precipice, and although the fall may appear to occupy the same place from year to year, it

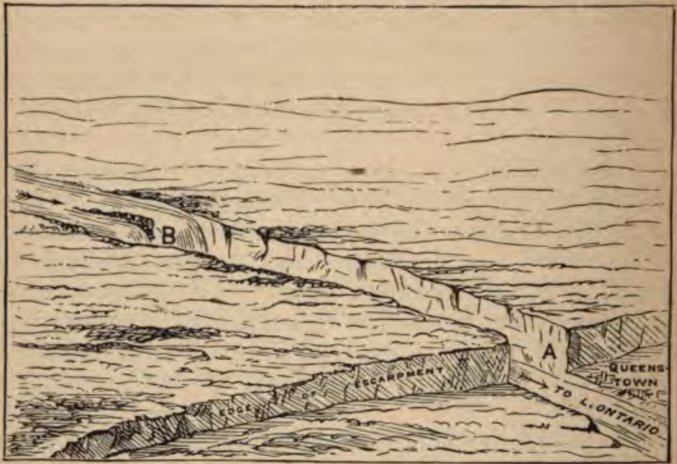


Fig. 72. Example of River Erosion.

is slowly creeping up stream and carving out a ravine as it does so.

All rivers are more or less discoloured, and after heavy rains the discolouration is more marked. It is evident, therefore, that the sediment acquired is being carried down stream. Now the faster a river moves the more capable is it of holding solid matter in suspension. A current moving at the rate of about half a mile an hour can hold fine clay or sand in suspension; if its velocity be about two miles an hour stones as large as an egg may be rolled along the bottom, and in the case of a swift mountain torrent, masses of rock weighing many tons are sometimes moved. Hence, besides the transportation of sediment by rivers, large portions of rock are pushed along the bottom, so that there is a constant carrying of materials from the higher portions of a river basin to the lower. The amount of solid matter moved in this manner is enormous, and its quality depends of course on the nature of the country through which the river passes. The Thames is said to carry past Kingston about 550,000 tons of mineral matter every year, and two-thirds of this is carbonate of lime, a substance which, as has been remarked before, is very soluble in water containing carbon dioxide in solution. The Mississippi carries down to the Gulf of Mexico nearly 1,000,000 tons of solid matter in suspension every day, and besides the suspended matter it is estimated that 75,000,000 cubic feet of earth, sand, and gravel is pushed along the bottom into the Gulf of Mexico every year, whilst these amounts are considerably increased during floods. The Ganges carries about 335,000,000 tons of mud past Ghazipur during the four rainy months, which amount is on the average $\frac{1}{430}$ of the weight of the average water discharge for the same period.

The solid matter carried into the sea by rivers represents the amount obtained from the whole area drained by the river, hence it is possible to calculate the amount the general surface of the land would have to be lowered to supply the material.

The rainfall of the Upper Ganges scrapes off one foot from the whole surface of its rain basin above Ghazipur in 1,146 years; and at the present average rate of work of the Mississippi a foot is scraped off the country drained in 6,000 years, an amount which would reduce the whole land surface to sea-level in 6,000,000 years.

When the basin of a river widens and the velocity of the current slackens, the solid particles can no longer be held in suspension, so much of it is deposited on the bottom of the river. After a river has flooded and gone down, the meadows and the flood plain altogether is left covered with a layer of fine mud or sand. The matter thus deposited by rivers is called **alluvium** or alluvial deposits. It is evident that the heaviest substances suspended in the water will be the first deposited and that the lightest substances will be deposited on the top.

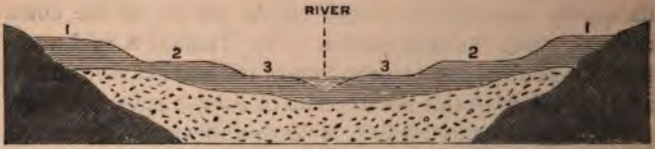


Fig. 73. The Valley of a River. 1, 1, 2, 2, 3, 3, represent river terraces at different times.

Such successive depositions may raise the level of the surrounding land, whilst the river channel is being deepened at the same time. The result is that a time comes when the flood of water cannot overflow the sides of the river, so it eats into the soils bordering it. This goes on during many years, the higher portions of the banks being carved out with each increase in the volume of the water, and eventually another flood plain is formed at a lower level than the first, and so on until a series of flood plains or river terraces are formed. These terraces are, therefore, made up of the mud, sand, and gravel deposited by rivers (Fig. 73).

The formation may not be strikingly marked, but there is always a gentle slope from the deep channel in which a river flows to high land on either side.

The river Rhone enters the lake of Geneva as a swift and turbid stream and leaves it clear and transparent, having deposited at the upper end of the lake soil brought from the Alpine slopes. Similar deposits occur when any river runs into the still waters of any lake; and the amount of deposit is, of course, greatest where the river meets the lake. At this point a kind of bar is formed which daily increases in size, and in time gets so high as to be above flood level; the deposit, however, continues, and the edge of the lake creeps inland. No better example of this action can be quoted than that of Port Valais, which once existed as a Roman port but is now about a mile from the edge of the lake of Geneva, the land between the port and the lake being entirely alluvium and must have been deposited during the last 1,800 years. By the same kind of deposition lakes are constantly being filled up with fine sand and mud, and in the course of time become marshy lands and green meadows. In precisely the same way that sediment is deposited and a barrier raised where a river enters the still waters of a lake, a deposit occurs when a river enters a sea or ocean where there is little or no current—a *bar* is formed. This deposit may slowly rise to the surface of the water and become a tract of marshy land which in time obstructs and divides the river, causing it to enter the sea by two or more mouths instead of one. The river, instead of receiving tributaries, as heretofore, breaks up into many branches, a few only of which enter the sea. The point where the river is divided marks the place where the deposit begins. Year by year more sediment is deposited and mainly where the river discharges into the sea, so that there is a constant growing out of land into the gulf or bay into which the discharge takes place. A typical example of this kind of formation is afforded by the Nile. At one time this river must have discharged itself into the Mediterranean at Cairo which is now, however, a hundred miles from the coast. The deposit from the two main branches has formed a trianglar area of land which has filled up the gulf into which the discharge formerly took place. The distance between the two mouths of the Nile at Rosetta and Damietta is 90 miles. There are many other mouths, however (Fig. 74), and the whole sea front between them is about 200 miles.

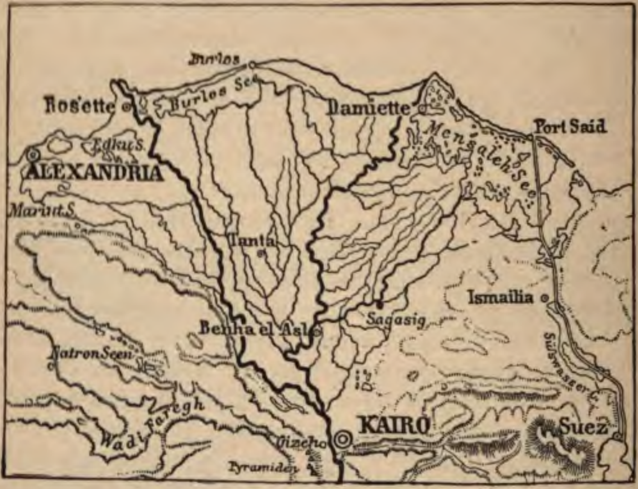


Fig. 74. The Delta of the Nile.

This triangular area of land which accumulates at the mouth of rivers is called a delta, because of its resemblance to the Greek letter Delta (Δ). The point where the deposit begins is called the head of the delta. The head of the delta of the Ganges is 200 miles from the sea and the area of the delta is about 8,000 square miles; these facts indicate that it is a very old formation. Indeed at Calcutta a boring of nearly 500 feet has been made without reaching the bottom of the alluvium deposit consisting of sand, clay, gravel, and some layers of vegetation. The delta of the Brahmaputra river joins that of the Ganges, and there is a distance of about 200 miles along the sea coast between the mouths of the main branches of these rivers.

Some borings in the Nile delta show that alternations of blown sand and alluvium continue to the depth of 120 feet below the surface, and then beds of gravel, pebbles, and other rocks occur.

These deltas, or lands formed by deposits of river mud, occur at the mouths of many rivers. It will, however, be understood that if a river opened into a sea where deep tidal currents exist, and in exposed coasts, there would be little or no formation, because the sediment would be removed as fast as it was deposited. This explains why deltas are common in such land locked seas as the Mediterranean and the gulf of Mexico, where there is little tidal effect. Such a river as the Amazon forms no delta, although it must deposit a considerable amount of matter into the sea. The solid matter is carried so far out into the sea, however, that no sediment occurs at the river's mouth. It is said that the waters of this river can be distinguished 300 miles from its mouth because of the suspended matter.

In the case of the Mississippi, the delta has long filled up the bay where the deposit first began, and long tongues of land are now being sent out far into the Gulf of Mexico. Venice and Ravenna stand on the delta of the Po, and the increase of the delta is so considerable that Adria, which was once a port on this river, is now 14 miles inland.

GENERAL SUMMARY OF CHAPTER XII.

Rocks are called permeable or impermeable, according to their character of allowing or not allowing water to readily pass through them,

A Surface Spring is formed by the simple sinking of water through rocks because of its own weight, and is immediately dependant on the amount of rainfall.

Deep-Seated Springs and Artesian Wells are formed by the percolation of water through rocks until an obstructing stratum is reached, when, in obedience to the law of hydrostatic pressure, it tends to rise to the surface with a force proportional to the height of the water accumulated in the permeable strata.

Spring water contains:—

(1.) Dissolved gases, carbon dioxide, oxygen, sulphuretted hydrogen, etc.

(2.) Mineral matter, carbonates and sulphates of calcium, magnesium, and compounds of sodium, iron, etc.

Temporarily Hard Water contains carbonates, and may be softened by boiling: **permanently hard water** contains sulphates and cannot be easily softened.

Streams are formed by rainfall and springs; when mainly dependant on rainfall they are called *temporary*, when arising from springs and increased by rainfall, *permanent*.

The definition of a River, given by Dr. Haughton, is as follows:—

'The surplus of rainfall over evaporation, seeking its way down to the sea level by the *path of least resistance*, which is the path of *greatest slope* or valley line.

Each river drains an area called its *rain-basin*, and the boundary lines of the rain-basins are called *water-sheds*, or lines of *least slope*, or *ridge lines*.'

The Source or Rise of a river is its highest, or longest, or most important water supply.

The Bed or Channel of a River is the hollow which it has scooped out in the land.

The Banks of a River are the margins of the channel in which it flows. On following a river downward the *right bank* is that on the right hand, and the *left bank* is that on the left hand.

An Affluent or Tributary Stream is one that flows into a larger one. The point where the junction takes place is called their **Confluence**.

The Mouth of a River is where the water is discharged into a lake, estuary, or sea.

The proportion of the Volume of Water discharged by a river to the rainfall received in its basin is dependent upon :—

(1.) The amount lost by evaporation.
(2.) The amount that sinks into the earth and finds its way to the sea by subterranean passages.
(3.) The amount that flows into the basin of some other river by subterranean passages.

Rivers do work in three ways :—

(1.) By erosion, or the breaking up of rocks by chemical or mechanical action.
(2.) By the transportation of materials dissolved in the water, or suspended in it, or by rolling them along the bed.
(3.) By the deposit of these materials in a different part of the bed or in the sea.

The conditions favourable to the formation of a Delta at the mouth of a river are :—

(1.) The water into which the river enters must be free from currents.
(2.) The velocity of the river must not be sufficient to carry it far out to sea.
(3.) A sheltered coast.

CHAPTER XIII.

GLACIERS AND ICEBERGS.

We have noticed that at a height above sea level, which, however, varies in different latitudes, there is a region where the moisture is always precipitated in the form of white powdery snow. In England the snow quickly disappears by evaporation or melting. In the region of perpetual snow, although there is still a loss by evaporation there is none by melting, hence an accumulation occurs; the first layer of snow has another layer piled upon it and so on for many other layers. The result of this accumulated weight is that the snow becomes very compact, for the same reason that fleecy snow-flakes when pressed together form a compact snowball, and the reason is that the air is, so to speak, squeezed out. The pressure increases with successive falls, and eventually the lower layers become so compressed as to be transformed into ice. If the layers of snow rested on a level plain and in the region of perpetual snow, the accumulation would reach a thickness of thousands of feet. At the bottom blue transparent ice would be found, at the top fine granular snow; indeed, it is believed, that in the Antarctic regions the thickness of the whole layers amounts to more than 10,000 feet. Such sheets of snow are called **snow fields.** It will be understood that if a snow field is formed on a slope there is a constant tendency for the mass to slide downwards. The valleys leading up into the snow field become filled with compact snow called *névé* or *firn*, and the pressure of the upper layers combined with the pressure at the side of the valleys, transforms these tongues into moving rivers of ice, which creep gradually down from the region of perpetual snow by the action of gravity. Such **a river of ice is called a glacier.**

That the glacier really moves is capable of easy demonstration by fixing a row of stakes or stones straight across it. In a few days the row will have become curved, and all the stakes or stones will be found to be lower down when observed with respect to the bank. The velocity of a river is always greatest in the middle, and least at the sides and bottom, owing to friction; for the same reason a glacier moves fastest at the centre and slowest at the sides and bottom, the result being that the row of stakes or stones laid down to investigate the motion become curved.

The rate of motion of course depends upon the slope of the valley down which a glacier is travelling. The large glacier of Chamouni, called the Mer de Glace, moves on the average about 24 inches in the centre for about 16 inches at the sides during 24 hours. The velocity, however, varies with the season; in summer the centre moves about 27 inches per day, in winter only about 15 inches.

When a river experiences a sudden fall the mobility of the water allows it to flow over in an unbroken stream as a waterfall. When there is a sudden fall in the level of the valley traversed by a glacier or ice-river an ice-fall is formed, but ice is not so mobile as water, hence this alteration in the level of the bed causes it to break up to a certain extent as it falls over, and crevasses are produced. Similarly, such splits are produced by the bending of a glacier from side to side, hence the surface of a glacier is rarely even, and wide chasms are often formed, which extend to the bottom. To complete the analogy with rivers, we have the fact that large glaciers receive tributaries. A river also drains a certain region of surplus rainfall, a glacier drains a region overburdened with snow and represents the escaping drainage of a region above the snow-line.

One or more continuous lines of stones, earth and gravel occur along the middle of a glacier, and similar lines may also be seen at the sides. Such formations are termed respectively

medial and lateral moraines, and represent work done by glaciers in the transportation of materials from a higher to a lower level. A river carries solid matter in suspension, a glacier carries the debris which falls upon it bodily downwards. Many of these fragments of rock have been detached by the action of the atmosphere in a manner already explained.

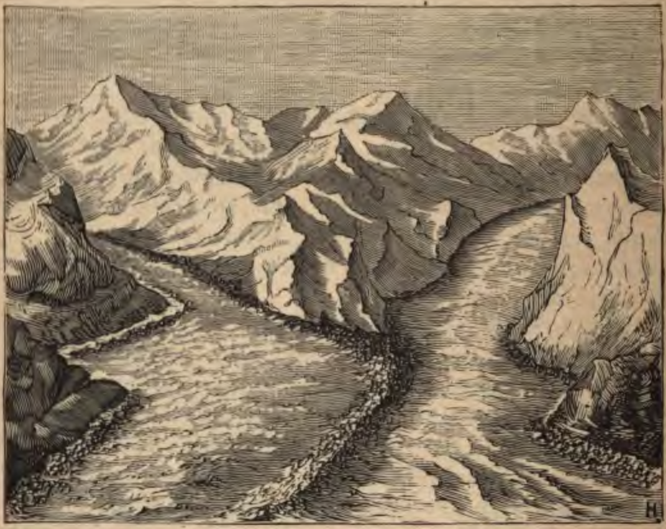


Fig. 75. Formation of Lateral and Medial Moraines.

Erosion is constantly going on all along the sides of the rocky valleys traversed by rivers of water or rivers of ice; fragments of rock, therefore, are constantly being loosened and fall upon the sides of the glacier, forming lateral moraines which are borne down the valley.

If a medial moraine, that is, the line of rubbish that occurs in the middle of a glacier, be traced upwards, it will be seen to be formed by the meeting of two of the lateral moraines of separate glaciers running into one. The mode of formation is shown in Fig. 75. In addition to the material transported downwards on the back of a glacier, large portions of rock fall into crevasses and are carried in the mass of ice, or may reach the bottom of the glacier. Such fragments wedged in the glacier share its motion, and, as they are dragged along, the sides and bottom of the glacier bed get scratched and ground up as if innumerable files and rasps were at work upon it, all sharp corners are rubbed off and the valley down which the glacier flows gets smooth and dome-shaped. It is evident that the scratching on the surface of the rock at the sides and bottom of a glacier will be parallel and have a general direction down the valley. From this fact it is possible to recognise where glaciers have formerly existed, and the direction in which they moved; and the distribution of striated and smoothed rocks as those described at the mountain summits in Northern Europe and North America show that these two parts of the earth have been under moving sheets of land ice, the same as Greenland is to day; and there is no doubt that many of the valleys of Great Britain were once filled with glaciers. The movement appears to have been from the high lands of Norway in every direction.

The rocks carried on the back of a glacier and those in the mass of ice itself are carried downwards until a point is reached where the ice is continually being melted. This point is not necessarily at the same height above sea level as the snow-line, and in some cases is much lower; but a point is always reached by a glacier where it slowly melts away into a stream of muddy water. The milky appearance of the water is due to the suspension in it of the particles formed by the grinding action against the surface of the glacier bed, of which we have already given a description. A glacier may thus become the source of a river and such a river will become more swollen in the summer, when there is more of the glacier melted away, than in winter. As the ice melts the striated fragments of rocks which have been fixed in the ice and pushed along the glacier are deposited, and also the rubbish that has been borne on the back of the glacier. The heap of stones and rubbish thus formed is called a **terminal moraine.**

Sometimes a glacier retreats and gradually leaves bare the valley in which it moved; this happens when the ice is melted quicker than it is supplied from the snow-field at the top. We may then see the effects of the motion of the glacier upon the rocks in its bed. No angular masses of rock can be found, for the grinding action previously referred to smooths and rounds them, so that they appear like the backs of a lot of sheep lying in the bed. Indeed such round topped rocks are known as *roches moutonnées* (sheep rocks). It is by the finding of these rocks in the Lake district and Scotland that we know Britain was once covered with ice. Besides these striated rocks that occur along the bottom and sides of the valley of an ancient glacier, all the material which was originally carried on the back and in the interior of a glacier gets deposited as the ice melts, and as the glacier gradually creeps up the valley a lot of material called glacial drift is distributed along the bottom.

The masses of rock that fall upon the back of a glacier are often transported to regions where none of the same character is naturally found. Many such masses of rock are found, and their angular shape and large size show that they must have been transported on ice to their present position.

If a lump of ice be placed in one pan of a balance, and weights put in the other pan so as exactly to keep it in equilibrium, after a time the pan of the balance which contains the weights will go down, thus indicating that the ice has lost in weight; this is because some of it has evaporated. In a like manner all glaciers experience a loss by evaporation from their surface, and this lowering of the surface is called the **ablation** of the surface.

That the surface is constantly being lowered is made evident by the fact that many large blocks of rock are found perched upon a pedestal of ice often ten or more feet high. Some of these 'perched blocks,' or 'rock-tables,' are shown in Fig. 76; the ice has evaporated all around the rock, but so much evaporation cannot go on under it, hence the rock grows up, as it were, out of the ice, although really it is the surface around the rock that sinks; after a time the pedestal becomes too slim to support the rock and it is dropped upon the ice to again be raised up as formerly.

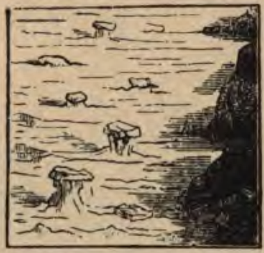


Fig. 76. Perched blocks.

When a glacier meets a lake or the sea, large masses of it break off and float on the surface of the water until they melt away. All such floating masses are called **Icebergs**; and since a glacier is formed primarily from snow all such mountains of ice are fresh. Sometimes the glacier is pushed out at once into deep water and huge fragments are broken off on account of their weight, at other times it is pushed along the sea bottom for some distance and eventually breaks off on account of the buoyancy of the ice (Fig. 77).

Everyone knows that ice floats on fresh water; much more then does it float on sea water, which is heavier, bulk for bulk, than fresh water at the same temperature. Only about one-ninth of the bulk of an iceberg floats above water, the other eight-ninths being below the surface. It often happens, however, that the part of the iceberg in the water is wasted away quicker than the visible portion, the result being that the iceberg gets 'top heavy,' and turns right over, causing great danger to any vessels in the vicinity.

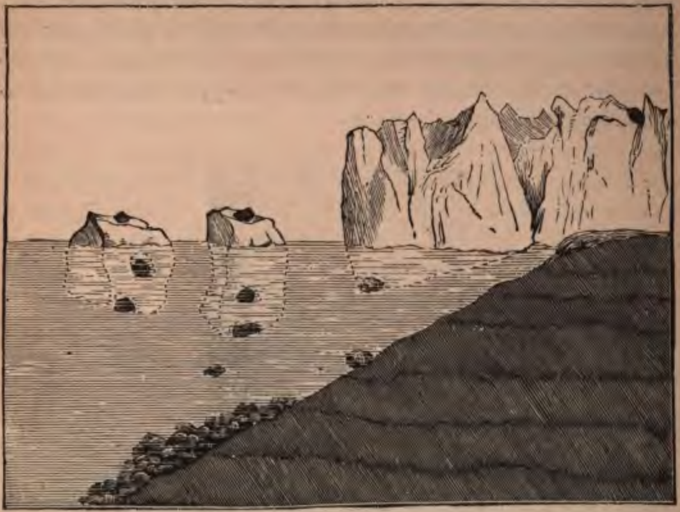


Fig. 77. Formation of Icebergs.

The freezing point of fresh water is, as we have previously remarked, 32° F. Sea water, however, does not begin to congeal until a temperature of about 26° or 27° is reached. During winter in the Arctic and Antarctic Oceans large areas of the sea surface get frozen over. First thin flakes of ice known as 'sludge' are seen; when this has thickened it is known as pancake ice, and finally a vast expanse of ice, known as an **ice-field**, is formed. Such an expanse is broken up and covered with hummocks, snow drifts and fissures. Towards the end of the winter the ice fields begin to break up into

Ice-floes or ice islands, a group of them being called **Pack Ice**, whilst a part is often broken up into smaller masses, known as **Drift Ice**. The shelf of ice that forms along the shore of Greenland by the freezing of sea water is known as the **ice-foot.** The formation often breaks off during the summer, and carries the *débris* from cliffs overhanging the shelf to distant regions, behaving, in this respect, like icebergs.

A great difference between an iceberg and an ice-floe is that one carries blocks of rock and rubbish into the sea and the other, being of marine formation, transports no such materials. As the iceberg melts its debris is dropped into the sea and deposited upon the sea bottom, this affording another example of how huge boulders of rock may be conveyed from one place to another.

No better account of ice and icebergs could be given than which Captain Nares appends to his 2nd report of the 'Challenger' expedition. He wrote:—'The icebergs met with by us were usually from a quarter to half a mile in diameter, and about 200 feet high; the highest measured was 248 feet high, but it was evidently an old berg floating on a large base; the largest was seen furthest south in latitude 66° 40′, it was certainly three miles in length, and was accompanied by several others nearly as large.

'They were all remarkably clear of rocks or stones, although each time we have dredged sufficient evidence was brought up that the bottom of the sea is fairly paved with the *debris* brought by them from the Antarctic lands.

'In shape they were very nearly tubular, the original top surface of the glacier remaining uppermost, or inclined at a slight angle to the horizon; in this cold climate they could not be otherwise unless they broke up in consequence of some local weakness . . . . The pack-ice consisted chiefly of small salt water ice pieces—they cannot be called floes—from 30 feet to 50 feet in diameter; 100 miles inside the pack-edge Ross found them to be 200 yards in diameter. The single season's ice was about 3 feet in thickness; the hummocky ice, formed by several layers of this heaped one upon another and frozen compactly together, was from 7 feet to 8 feet thick, the upper surface of each piece being covered by a layer of snow about a foot in thickness. Scattered about in the pack were a few blue coloured berg pieces of all sizes, some of them frozen into the salt water ice. All the latter were much honey-combed by melting, but it was evidently still of sufficient strength to give a very dangerous blow if accumulated against a ship's side, or to a vessel forcing her way through the pack. A properly fortified ship could have made way through most of what we saw, and it certainly does not deserve the name of a "barrier" given to it by Wilkes, although he was perfectly justified with his unfortified ship in keeping outside it.

'In the pack were numerous icebergs, but they were not in greater numbers than we found in the open water, and certainly not numerous enough by themselves to create the nucleus for the pack to form upon.

'When at the pack-edge the temperature of the water was always between 28° and 29°, just sufficiently warm to melt salt water ice very slowly, but to have no effect on the fresh water berg pieces. At a short distance from the pack the surface water rose to 32°, but at a depth of 40 fathoms we always found the temperature to be 29°; this continued to 300 fathoms, the depth in which most of the icebergs float, after which there is a stratum of slightly warmer water of 33° or 34°.'

GENERAL SUMMARY OF CHAPTER XIII.

A Glacier is a river of ice draining a tract above the limit of perpetual snow and removing the superabundant snow to regions below the snow-line.

The Rate of Movement of a glacier varies with the slope, the season, and the snow-fall; it is greater at the upper surface than at the lower, and greater in the middle than at the sides.

Moraines.—The lines of stones and gravel that run along the sides of a glacier are called *lateral moraines,* those that lie along the centre are *medial moraines*, and that deposited at the end is called a *terminal moraine.*

That Glaciers once existed over North America and Europe is proved by the old terminal moraines, striated rock surfaces, and transported angular blocks and drifts, such as would be left by retreating glaciers, found in the valleys.

Icebergs represent the discharge of glaciers and consist, therefore, not of frozen sea water but of land ice.

An Ice Field is an expanse of ice formed by the freezing of sea water and the limits of which are not visible.

An Ice Floe is a detached portion of an ice field. They differ from icebergs in not carrying debris and in being frozen sea water.

An Ice Foot is the shelf of ice formed by the freezing of sea water along the coast. It is sometimes the means of transporting rocks to other regions in a similar manner to icebergs.

CHAPTER XIV.

LAKES, SEAS AND OCEANS.

When the slopes of a country are fairly uniform the surface waters are carried into seas and oceans by streams and rivers; if, however, an unusual depression of the land surface occurs, the waters accumulate in it and form lakes or sometimes wet marshy ground called morasses.

All such large bodies entirely surrounded by land and not directly connected with the sea are called lakes, and the area whose drainage feeds a lake is called a lake-basin.

An inspection of a map of the globe shows that lakes are most numerous in the north temperate zone; in fact, the great lakes of North America, the Caspian Sea, Lake Aral, Lake Balkash, and Lake Baikol in Asia, and the Mediterranean Sea in Europe form a circle of enclosed collections of water.

Many lakes lie in hollows scooped out of the solid rock and as these usually occur in high latitudes they are said to have been formed by glacier action. The scratchings and general character of the adjacent rocks often demonstrate the movements of ice that have occurred. It is very doubtful, however, whether glaciers can scoop holes in solid rocks, and the more probable supposition is that such rock basins existed before the glacier movement and were filled with decomposed rock material which was scooped out by the action of the glacier ice. When a glacier retreats up the valley owing to an insufficient supply of ice, a heap of stones and rubbish is left which dams up the valley so that the water from the melting ice may form a lake; indeed, the lake of Geneva is entirely fed by the melting of the ice of a glacier. Other lakes are found, not in solid rock, nor in a rocky valley stopped up at the lower end, but lying among stones and other rubbish once borne on the back of a glacier and deposited as the ice melted.

Some lakes, like those in Central Italy, are found in volcanic districts, filling up the craters of extinct volcanoes or the openings that have been formed by eruptions.

When the waters of a lake rise, an outlet for the surplus water may or may not be found. In the latter case, if the land surrounding the lake has little slope there will be a much greater area of water surface when the level of the lake is high than when it is low, hence there will be a much greater amount of water lost by evaporation and this may equal the amount brought into the lake.

We may, in fact, say that when a lake has no outlet and does not overflow in any way, the evaporation from its surface exceeds the supply brought by the tributaries; this excess of evaporation over supply goes on until the lake has fallen to such a level that the evaporation from its surface is equal to the supply of water. In the case of the Dead Sea this process has been carried so far that its level is 1,350 feet below the level of the Mediterranean. The Caspian Sea covers a surface larger than the British Isles, and its surface is 85 feet below sea-level.

Now when a lake has an outlet, the water in it, like the water of its tributaries, is almost always fresh; lakes having no outlet, however, contain salt, bitter water. The latter class of lakes are supplied with water by the many streams which run into them but send no rivers out. We know, from what has been previously said, that all streams contain a certain amount of mineral matter; such dissolved matters are, therefore, carried into lakes. If the lake has no outlet and the level of the water does not rise, we know that the surplus water is being carried off by evaporation into the atmosphere; but water-vapour, be it formed by slow or rapid evaporation, is always pure, hence a lake without an outlet is constantly losing pure water by evaporation and the dissolved salts are being left behind. Such lakes, therefore, gradually get more salt and bitter, until—when the water has become saturated with any particular salt—the continuation of evaporation causes it to be deposited in a layer at the bottom of the lake.

Some examples of bodies of salt water of the character described are the Caspian Sea, Dead Sea, the Sea of Aral and the Great Salt Lake in North America. A pound of water taken from the Dead Sea and carefully evaporated would leave behind a quarter of a pound of solid matter, which is about seven times the amount that would be found in ordinary sea water; of this about 25 per cent. would be common salt, and about 75 per cent. chlorides and sulphates of calcium and magnesium. A pound of water from the Great Salt Lake would on evaporation be found to leave nearly 2½ ounces of solid matter, 79 per cent. of which would consist of common salt, about 10 per cent. chlorides and sulphates of calcium and magnesium, and the remaining 11 per cent. would be made up of various other substances.

In the case of ordinary river water and the water of such lakes as Lake Superior and Lake Michigan in North America, the proportion of common salt is only a little over 3 per cent., carbonates of calcium and magnesium about 70 per cent., and various other substances make up the remaining 27 per cent. From a comparison of these facts, therefore, it appears that chlorides and sulphates of calcium and magnesium form the largest proportion of the mineral matter in so-called salt water lakes and seas, and carbonates of these elements occur in the greatest proportion in the average fresh water lakes.

A lagoon is a lake occurring in low lying land near the sea, and separated from it by a narrow beach of sand and gravel. The drainage of the coast runs into such maritime sheets of water, and if the outlet to the sea be small, or if the water filters into the sea through the porous bar separating the two sheets of water, a lagoon of fresh water is the result; if, however, the outlet is large, the sea water flows into the lagoon and the water becomes salt.

The deposit of solid matter in lakes, owing to the checking of the current of their tributaries, has already been explained, and it is evident, therefore, that the bottom of all lakes must be rising, and that there is a tendency for all such bodies of water to get filled up and to form rich **alluvial plains** or **lake-lands.**

An examination of the course of a river would show that in places it runs across plains of alluvium land that has become covered with grass and converted into green meadows. The hollows doubtless existed as lakes or ponds into which the river once flowed; as it spread out over the larger area its velocity was decreased and sediment was deposited, the result being that the hollow was gradually transformed into an alluvial plain traversed by a river of the ordinary form.

One of the parts played by a lake is to act as a preventative of floods; the water from the tributary streams gets spread out over such a large area that even when the supply is enormously increased the effect on the out-flowing river is not great. The presence of large sheets of water also serves to equalise the temperature during the different seasons of the year. In the summer the water does not get hot so quickly as the land, and in the winter it does not lose its heat so readily, so that it cools the air in summer and warms it in winter.

In fact, it has been calculated that during five cold nights of December, 1879, the Lake of Geneva gave out to the atmosphere as much heat as would have resulted from burning 1,200,000 tons of coal.

From lakes and inland seas cut off entirely from the ocean, enclosed seas like the Mediterranean, Baltic and Black Seas, and partially enclosed seas like the North Sea and China Sea, we pass to a consideration of the larger water surfaces of the earth.

About three quarters of the whole surface of our globe, or 145,000,000 square miles, is covered with water. This enormous area is divided into several branches or compartments by masses of land, and a particular name has been given to each division, but really the water forms one continuous whole.

If we take a globe and set it so that London is at the top, it will be manifest that we shall be able to see a hemisphere of the globe, and inspection would show that most of the hemisphere visible consists of land. The other hemisphere, however, would be seen to consist almost entirely of water surface. London, in fact, is nearly the centre of the land surface of the earth and Antipodes Island, near New Zealand, is nearly the centre of the water surface.

The following are the five great divisions of the water surface of the globe, with their distinctive names and general position relative to the continents :—

The Pacific Ocean, separating Australia and Asia from America.

The Atlantic Ocean, separating Europe and Africa from America—the Old from the New World.

The Indian Ocean, lying between the Antarctic circle and the south of Asia and separating Australia from Africa.

The Arctic Ocean, lying within the Arctic circle.

The Antarctic Ocean, lying within the Antarctic circle.

The first three of these oceans are great highways of traffic between the continents; the two remaining are not important in this respect, but in them, and in the former especially, a considerable amount of valuable whale fishery goes on.

The numbers contained in the following table will give an idea of the comparative size of these oceans.

	Greatest Length miles	Greatest Width miles	Area sq. miles	Average depth miles
Pacific Ocean ...	9,000	12,000	67,000,000	3
Atlantic " ...	9,000	3,600	34,000,000	2½
Indian " ...	5,500	6,000	28,000,000	2¼
Antarctic Region	3,300	3,300	7,000,000	1
Arctic Ocean ...	3,300	2,500	5,000,000	1

These figures are not correct to any great degree of accuracy, and must be accepted with a certain amount of caution. They show, however, that there is a much larger amount of water in the southern than in the northern hemisphere, for in the former the Antarctic, Pacific, Indian and Atlantic Oceans all meet and form a belt completely surrounding the earth.

The old method of determining the depth of the ocean was by means of a heavy piece of lead attached to a rope, but on account of under-currents the rope rarely went down vertically, and exaggerated results were obtained. The apparatus used during the expedition of H.M.S. 'Challenger' (1872–76) was invented by Lieutenant Brooke and is as follows.—A brass tube about two inches in diameter, and having a pair of valves opening inwards at the lower end, is attached to a sounding line of wire. An iron washer is held on the tube about 18 inches from the end by means of a wire sling, and on it rest three or four sinkers, each 56 lbs. in weight. When the sounding line has been paid out sufficiently, the tube strikes and is forced into the bottom of the ocean floor as far as the height of the bottom cylindrical sinker. As soon as the sinkers touch the bottom, however, the sling supporting them is thrown off the arrangement at the upper end of the tube; the tension on the line is thus considerably lessened, and the tube, containing a sample of the ocean bottom, is drawn up to the surface for examination, whilst the sinkers are left behind (Fig. 78).

From many observations of oceanic depths it seems to be established that the average depth is 2000 fathoms, or about

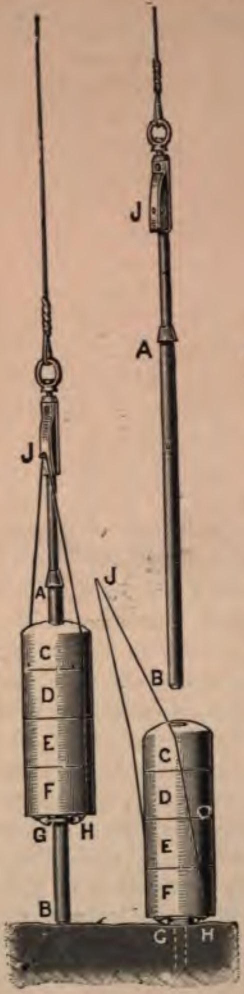


Fig. 78. The Hydra Sounding Rod. A B is a hollow tube having a valve opening inwards at B. C, D, E and F are weights resting on the washer G H, which is kept in position by means of the wire sling at G J H. When the washer touches the ocean floor the sling is thrown off and the tube is then drawn up.

two and a half miles (1 fathom = six feet), and that it probably *nowhere* exceeds 5000 fathoms. The depths below 4000 fathoms are local and seem usually to be pits in the earth's crust formed by volcanic action.

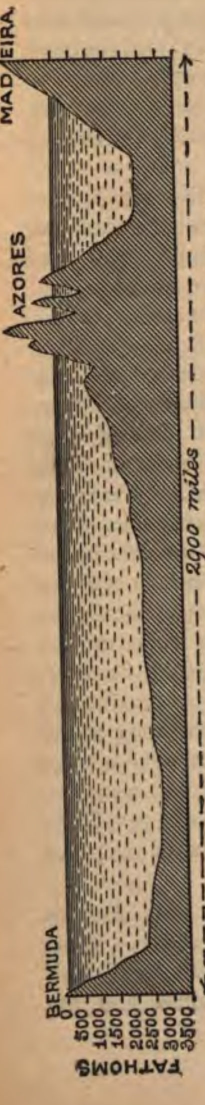
All the oceans lie in great depressions, and these depressions run, to a certain extent, parallel with the axis of the neighbouring continent. We have previously remarked upon the once molten condition of our globe. As it cooled down and got wrinkled like an old apple the vapour surrounding it was condensed, and as it fell upon the earth's surface in obedience to the laws of gravity it flowed towards the lowest point and so filled up the hollows and formed seas and oceans. Other causes, however, have been at work since that distant epoch. The depressions on the earth were converted into seas and oceans, and the higher parts of the land were left to be battered and broken up by copious rain fall and other atmospheric agencies, and the disintegrated products to be washed into the ocean by rivers. Hence all the ridges that occur on the ocean floor are not sharp and bold as those that make the earth's surface picturesque; they are covered with deposit, smooth, and not much above the general level. Hill and valley occur on the ocean floor, but all hollows get gradually filled up, so that it appears like a vast undulating plain, varied here and there by a volcanic cone which, rising above the surface of the water, forms a volcanic oceanic island.

It is interesting to know what is the proportion of land above the sea level to the volume of the water contained in the depressions. The height of the highest mountain above sea level is about five miles, and the greatest depth yet sounded is also five miles. From careful estimations it has been found that the volume of land above sea level is 140,000 cubic miles; the volume of water in the oceanic depressions, however, is about 3,000,000 cubic miles, hence, the ratio of the volume of land to the volume of water is approximately as 1 is to 22; that is to say, the land that is above sea level might be contained 22 times in the ocean basins.

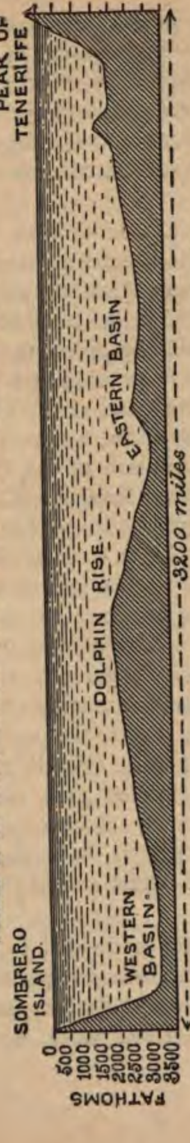
It can be well understood from the analogy with a wrinkled apple that some ridges of relatively higher level must run along the ocean floor. The water is of sufficient depth to completely submerge them, nevertheless they separate two deeper parts and have a sort of parallelism with the axis of the continent near it. The soundings obtained during the Challenger expedition show that there is a ridge running along the middle of the Atlantic from Iceland to the Antarctic Continent. Upon this ridge are situated the volcanic islands of the Azores, Ascension, and Friendly Islands, St. Helena, &c. The average depth of water on the ridge is 1,500 fathoms, and the average depth on both sides of the ridge is 2,500 fathoms. The greatest depth obtained in the Atlantic was immediately north of the Virgin Islands, where there is a hollow 3,875 fathoms or nearly 4½ miles deep. At this great depth the pressure of the water was nearly 4½ tons on every square inch of surface, and the glass thermometers sent down to register the temperature were crushed under the enormous pressure.

If we could travel from the west of Ireland to Newfoundland, and could measure the depth of the water at various parts, we should find that the least depth was 1,750 fathoms, and the greatest 2,424 fathoms. The bed of the Atlantic between these points has few irregularities, and consists of extensive levels covered with a grey mud which on examination would be found to consist chiefly of the shells of the minute animalculæ found in abundance on the surface of the sea. This submarine plateau is known as the 'Telegraph Plateau,' because on it were laid, in 1865-66, the submarine telegraph cables between England and America.

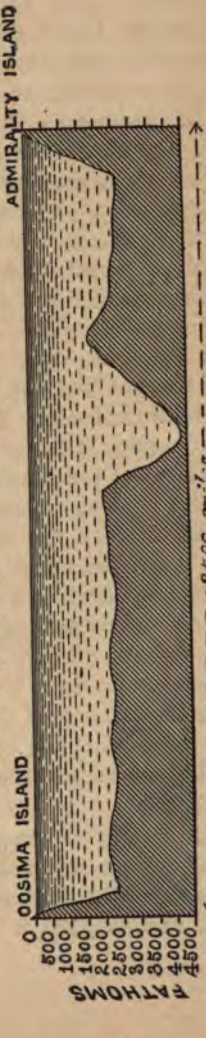
The Pacific Ocean appears also to be divided by a submarine ridge running along its greatest length from North Chili to Japan. The bed of the North Pacific, however, differs considerably from that of the North Atlantic, inasmuch as it does not present extensive levels but is somewhat abruptly unequal. Captain Nares, the chief of the Challenger sounded



Section of the North Atlantic Ocean between Bermuda, Azores and Madeira.



Section of the North Atlantic Ocean between Sombrero and Teneriffe.



Section of the North Pacific Ocean between Japan and Admiralty Island.

Fig. 79.

4,575 fathoms (about 5 miles) near the Admiralty Islands at Papua, and Lieutenant Belknap, of the United States Ship 'Tuscarora,' reached 4,643 fathoms outside of the northern extremity of the ridge on which Japan stands, these two soundings being the greatest reliable ocean depths ever recorded. Some sections of the Atlantic and Pacific Oceans are shown in Fig. 79.

The continents, three in the northern hemisphere, Europe Asia and North America, and three in the southern hemisphere, Africa, Australia, and South America, are simply masses of relatively high land which, in the cases of Europe, Asia, and both Americas, rise gradually from the sea shore to the interior. Great Britain was once joined by dry land to the other parts of the European continent. This is indicated by the remarkable shallowness of the sea at the Straits of Dover, and the similarity in constitution of the chalk cliffs of Kent and those of Northern France. Similarly, New Guinea was once joined to Australia. In fact, about 99 per cent. of the whole land surface of the globe simply consists of protrusions above the level of the sea from what is well termed the continental plateau. The remaining regions of elevation occur in detached areas, the largest of which lie in the Pacific Ocean and about the South Pole. The rocks which make up the numerous islands in the Pacific are entirely different, however, from those composing the greater part of the continents, and give reason to believe that these islands are the tops of old volcanoes through which molten rock was formerly ejected from the interior of the earth. Such cones are often capped with coral when rising nearly to the surface, and at a lower level are covered with the shells and skeletons of deep sea organisms.

The weight of any substance divided by the weight of an equal volume of water is termed its specific gravity. Thus, if we took a bottle which would contain exactly 1 lb. of fresh water and weighed it full of sea water, we should find the weight would be from 1·02 to 1·03 lbs. Hence the specific gravity of sea water is about 1·025. If the sample were taken from a depth of about 2,000 fathoms, it would weigh 1·05 lbs. It can be understood, however, that the water at great depths in the ocean must be enormously compressed since the lowest layers have all the rest piled upon them, so to speak. Indeed, if the water were not compressed at all, but existed as a mass uniform in specific gravity from top to bottom, the ocean would rise more than 500 feet above its present level.

The specific gravity of sea water is greater than that of fresh water because of the dissolved salts it contains. These salts amount to about 3½ parts in 100 of water, hence if we took 100 ounces of sea water and evaporated it we should get 3½ ounces of solid matter left. This is in the case of a sample taken from one of the oceans. The waters of the Dead Sea, or any such an inland sheet of water, has a proportionally much greater specific gravity (1·227), and contains 26·4 per cent. of solid matter.

Of the solids dissolved in sea water a little more than three-fourths consists of common salt, the remainder being made up of numerous other minerals of which magnesium chloride, Epsom salts (magnesium sulphate), and gypsum have the largest proportions. An idea of the magnitude of the dissolved salts may be obtained from the fact that, if all the water in the ocean were evaporated, the layer of salts left on the ocean bed would be 170 feet thick, and nearly 130 feet of this would be made up of common salt.

Where the evaporation is great, such as in the north and south Atlantic, owing to the trade-winds constantly blowing there, the specific gravity of the surface water is greater and its saltness is also increased. The water of the ocean is freshest, therefore, at the poles and equatorial belt of calms, while no part of the open ocean contains water so salt as that in inland seas such as the Mediterranean, the Red Sea, and the Persian Gulf.

Since all the streams that run into the ocean take into it a small quantity of earthy matter, it is likely that the waters of the ocean have dissolved in them a small quantity of every element. It is found that the proportion of each salt present in sea water, with the exception of calcium carbonate, is the same whether samples be taken from the surface, or at a great depth. In the case of calcium carbonate the amount dissolved increases slightly with the depth, because the water contains more carbon dioxide owing to the greater pressure, the carbon dioxide being produced by the decay of animals and plants, and to a much greater extent by the submarine volcanoes which must exist at the sea bottom.

Oxygen and nitrogen are absorbed by the surface waters of the seas from the atmosphere, and their presence in the water allows the existence of the living organisms that are found. The amount of the gases dissolved are in the proportion of $\frac{1}{4}$ carbon dioxide, $\frac{1}{4}$ oxygen, and $\frac{1}{2}$ nitrogen, the whole quantity having a volume from 2 to 3 per cent. the volume of the sea.

A certain amount of organic matter brought down by rivers from the land, and from the decay of animal and vegetable life, is also contained in sea water and serves as food for some of the animals living in it.

The increase of the amount of dissolved matter in the ocean is mostly prevented by the requirements of the plants and animals that exist in it. For example, the hard parts of the bodies of shell-fish and corals consist of calcium carbonate, and this material is obtained from the sea water by them.

The sounding rod used during the Challenger expedition gathered specimens of the bottom deposit. From the land for about 200 miles the materials met with are sand and clay, brought down to the sea by the rivers; but beyond this limit the deposit is of quite a different character; hence they have been divided into **terrigenous or shore deposits,** and **abysmal or deep sea deposits.** Over a great part of the Atlantic, Pacific, and Indian Oceans, between 300 and 3,000 fathoms, a fine white mud, much like powdered chalk, was brought up and is known as Globigerina ooze. It consists almost entirely of shells so minute that 15,000 of them would lie on a square inch, of a genus of animalculæ called the Globigerina, belonging to the group Foraminifera (Fig. 80). In some places the calcareous ooze consists of the thin transparent shells of another class of animals called Pteropods.

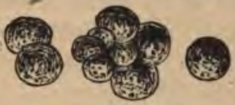


Fig. 80. Globigerina Ooze. Magnified about 25 times.

If we examined a few specimens of Foraminifera dredged from the ocean, they would be seen to be made up of variously shaped shells perforated with minute holes through which fine threads of the creature's body protruded. On the death of such animals, the jelly-like portion decays and the hard skeleton, being no longer supported in the water by it, falls to the bottom and forms beds of limestone and chalk.

There is another class of gelatinous animals called Actinozoa, and a particular species of this group is the **coral polyp.** The body of this animal is a speck of soft jelly having numerous arms similar to those of the sea-anemone. The polyp attaches itself to some submarine rock, secretes calcium carbonate from the sea water and deposits it on the rocks; it thus becomes fixed, and multiplies by budding and sub-division, each division going through the same stages as the parent. When the coral polyp dies, the soft parts of its body decay and are washed away whilst the hard part remains where it was deposited, and assists to build up the calcium carbonate into the most beautiful forms.

In the middle and western Pacific a different deposit called Radiolarian ooze was found, but at somewhat greater depths than the Globigerina ooze. This material consists of the minute shells of an organism called Radiolaria (Fig. 81), having the property of secreting silica from the sea water; the difference, therefore, between these and those described above is that one class has a calcareous and the other a siliceous shell. Another material called Diatomaceous ooze is mainly found in the Antarctic, south of the Cape of Good Hope, at depths between 1300 and 2000 fathoms, and consists of the remains of microscopic plants called diatoms, that live on the surface of the ocean and also secrete Silica, which, when they die, falls to the bottom of the ocean as a white sandy deposit.

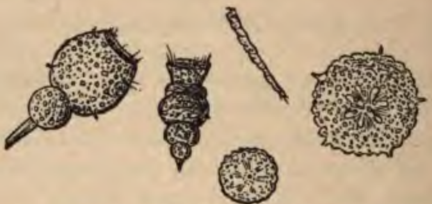


Fig. 81. Radiolaria Ooze. Magnified about 100 times.

At great depths in the ocean, far removed from the continental plateau, no calcareous shells are found, but only red and grey clays, termed Abysmal Clays. This is the case even when the Globigerina are very numerous on the surface. The absence is accounted for by the fact that at great depths the sea water, on account of the great pressure, contains a greater amount of dissolved carbon dioxide than the water at higher levels. The calcium carbonate, therefore, of which the shells are composed, gets dissolved and carried away in solution before they reach the bottom; at depths not quite so great, the thinnest shells get dissolved and the coarsest only are deposited. Siliceous shells can of course exist at all depths in the ocean.

If we dissolve all the calcium carbonate out of some Globigerina ooze by means of a weak acid, a small quantity—

about one per cent—of red clay is left. It is probable, therefore, that some of the abyssal red clay deposit represents decomposed Foraminifera shells. Most of this deposit, however, has a volcanic origin and is the result of the disintegration of pumice stone by the action of the carbon dioxide in the water. This red clay has the same composition as that seen in many districts, and consists almost entirely of silicon, oxygen, and another element called aluminium, the combination of the three forming silicate of aluminium.

The red clay also contains an abundance of minute specks of iron, which, doubtless, represent the remains of some of the 400,000,000 meteoritic particles that enter our atmosphere every twenty-four hours.

All the forms of life found in the ocean are most numerous near to the continental plateau, where there is shallow water and abundance of food in the shape of calcium carbonate and silicon brought down by the rivers. Another reason why the number should diminish with the distance from the continental plateau is that in all probability all deep sea animals have their origin in shallow water and have migrated from that locality. At a depth of half a mile there are no plants but still numerous animals. At the depth of a mile the majority of the animals met with are of an entirely different species from those near the surface; the same species of animals are found, however, in all the oceans at about the same depth.

GENERAL SUMMARY OF CHAPTER XIV.

Lakes may be classified with respect to their occurrence as follows :—

(1) Those occurring in hollows scooped out of solid rock.
(2) Those enclosed among heaps of glacier drift.
(3) In vast table-land depressions where there is a copious rainfall.

(4) Along low and sandy sea-coasts.
(5) In craters of extinct volcanoes and cavities formed by explosions.

Lakes having an Outlet generally contain fresh water; those having no outlet contain brackish water.

Lakes may derive their Water from one or more of the following sources:—

(1) Tributary streams.
(2) Glaciers.
(3) Springs which rise beneath them.

From Soundings of the Ocean it has been found:—

(1) That the sea bottom is flat compared with the land surface.
(2) That the mean depth of the ocean is about 2½ miles. (The mean height of the land is about 2000 feet.)
(3) That broad ridges or plateaus extend along the greatest length of the Atlantic and Pacific Oceans, and short ones in the Indian Ocean.
(4) That some islands, such as St. Helena, Trinidad, and the Azores, rise very abruptly from the deeper parts of the ocean bottom.
(5) That the continents are elevated plateaus separated by an abrupt line of demarcation from the ocean basins.

The following are the **Specific Gravities of some different Waters**:—

Pure Water	1·000
Atlantic Ocean	1·026
Mediterranean Sea	1·029
Black Sea	1·013
Dead Sea	1·227

Sea Water has dissolved in it:—

(1) Solid matter
(2) Gaseous „
(3) Organic „

The general average of solid matter is $3\frac{1}{2}$ per cent.

The Deposits found on the Sea Floor are divided into classes according to the depths, at which they occur. These are:—

(1) Terrigenous, or shore deposits.
(2) Abysmal deposits; that is, oceanic oozes and clays.

The Depths at which these Deposits Occur, and the estimated area, are shown in the following table:—

		Mean depth in fathoms.	Area in square miles.
Oceanic Oozes and Clay	Red Clay	2727	50,289,600
	Radiolarian ooze	2894	2,790,400
	Diatom ooze	1477	10,400,600
	Globigerina ooze	1996	47,752,500
	Pteropod ooze	1118	887,100
Terrigenous Deposits	Coral sands and muds	710	3,219,800
	Other terrigenous deposits, blue muds, &c. ...	1016	27,899,300

CHAPTER XV.

OCEAN CURRENTS.

If our globe were completely surrounded by water the influence of the trade winds and the earth's axial rotation would cause a continuous stream, filling the entire width of the tropics, to flow from east to west. But the continuity of this current is broken by the eastern shores of the three great continental masses; part being deflected towards the north, and part towards the south and, since we have shown that the trade-winds appear to blow from the north-east and south-east—in consequence of the excess of velocity of the air at the equator over that in higher latitudes—currents of water must be similarly affected. In fact, in the words of Professor Ferrel, an American meteorologist, it may be said, 'In whatever direction a body moves on the surface of the earth, there is a force arising from the earth's rotation which deflects it to the right in the northern hemisphere, but to the left in the southern.' Unlike the system adopted in the naming of winds, however, which are named according to the direction from which they blow, currents of water are named according to the direction towards which they are flowing.

In all the great oceans near the equator there is a broad stream of warm water flowing in a westward direction, the so called **Great Equatorial Current.** In consequence of the fact that there is much more water in the southern than in the northern hemisphere, the heat equator does not coincide with the geographical equator, but lies in 6° north latitude. Above and below this line the north and south equatorial currents flow.

When the stream of water strikes the eastern shores of Africa, or America, or the islands of the East Indian Archipelago, it is broken up, some being caused to flow towards the north and some towards the south. But in accordance with the law we have just enunciated, the northerly current is deflected towards the right hand, that is, east, strikes the western shores of one of the continents, and is turned again into the great equatorial stream; a sort of enormous vortex of water is thus formed, rotating in the same direction as the hands of a watch.

The portion of water deflected towards the south deviates to the left hand, that is, also to the east, because of the rotation of the earth, strikes the western shores of one of the continents, and is caused to flow into the equatorial current like its northern counterpart. Hence in the southern hemisphere the vortex motion is in the opposite direction to the hands of a watch. Since, therefore, there are three land masses to deflect the equatorial current, there should be six great systems of oceanic circulation, three right-handed vortices of water in the northern hemisphere, and three left-handed vortices in the southern hemisphere.

Let us now consider more particularly these systems of currents and others to which they give rise. The Atlantic Equatorial Current flows from the coast of Africa, strikes upon the east coast of South America, and is split in two portions near Cape Roque. One of the branches runs southward along the coast of Brazil as a stream of warm water called the **Brazil Current**, bends towards the east near the mouth of the La Plata, flows back towards Africa, and is deflected northwards into the great equatorial current; the circulation taking place in the opposite direction to the hands of a watch, the current being in the southern hemisphere. The other branch sweeps along the coast of Guiana as the **Guiana Current**, through the Caribbean Sea, and following the shores of the Gulf of Mexico, finally emerges through the Florida Strait.

North of this strait the current from the Gulf of Mexico joins a large portion of the north equatorial current that has crossed the Atlantic from Cape Verde Islands, and the united current of warm water flowing northwards is called the **Gulf Stream.** The average surface temperature of the Gulf Stream at this point is about 75 degrees Fahr. At the narrows of Bemini its width is about 32 miles, its depth is about 3,000 feet, and the velocity at the middle is nearly five miles an hour. As the stream flows on its depth decreases and its width increases, owing to the rising up and spreading out of the warm water of which it consists over the surface of the ocean, and with the increase of width the velocity diminishes. When this stream flows past Newfoundland, which is 1,800 miles from Cape Florida, its velocity is only a little more than a mile an hour, its width is more than 300 miles and its depth nearly 200 fathoms. At a distance of 3,000 miles from Cape Florida, in latitude 47° N., the stream bifurcates, that is, a forking or division into two branches takes place. The two branches flow respectively in a north-eastern and a south-eastern direction, and at the point of bifurcation each of the branches may be regarded as being 400 miles wide, and having a temperature about eight or ten degrees above that of the water on either side.

The branch that flows towards the south-east in consequence of the earth's rotation, passes along the west coasts of Spain and Africa, and finally mixes with the great equatorial current off the coast of Guinea as the **North African** or **Guinea Current.** This branch, therefore, completes the right-handed vortex of water in the North Atlantic. The centre of such an oval whirl of water is comparatively still, and over a considerable area in this portion of the North Atlantic grow dense masses of a rootless seaweed known as *Sargassum bacciferm*, and the part of the ocean where the growth occurs is known as the Sargasso or Grassy Sea. The north-eastern branch of the Gulf Stream, sometimes called the **Gulf Stream Drift,** flows slowly on and reaches the shores of the British Isles, Norway, and Spitzbergen. Between Iceland and Scotland the width of the drift is 600 miles and its velocity is not much above half a mile per hour.

The Gulf Stream proper, however, only consists of that portion which completes its circuit in the North Atlantic by joining the great equatorial current, and therefore ends near Newfoundland, hence it is somewhat incorrect to say that the Gulf Stream reaches our shores.

The amount of heat carried from the torrid into the temperate zone by the Gulf and other streams, has been a matter of much discussion. Dr. Croll estimated the mean temperature of the Gulf Stream as it passes the Strait of Florida as 65 degrees, and supposed that the water in its course becomes ultimately cooled down to 40 degrees. On this estimate the amount of heat transferred from the Gulf of Mexico by the Gulf Stream every day amounts to one fourth of that received from the sun in a year by the whole of the Atlantic Ocean from the tropic of Cancer to the Arctic Circle. These figures were obtained by taking the average width of the stream as 30 miles, the average depth as 1,000 feet, and the velocity as 2 miles an hour. Dr. Haughton estimated the stream as equal to a current conveying 38 cubic miles of water past some point every hour. On this assumption it is concluded that the Gulf Stream carries out of the tropics into the North Atlantic Ocean more than one-twelfth of the total heat received in the year from the sun by the torrid zone.

We shall treat of the effect of the Gulf Stream upon the temperature of the land in its path in the chapter on climate.

A system of oceanic circulation, similar to that which occurs in the North Atlantic, is also found in the Pacific Ocean. The North Pacific Equatorial current flowing towards the west from America impinges upon the coast of China, and is broken up into several portions. One of the main branches sets southwards past Australia and New Zealand, into a current flowing from the Antarctic Ocean, a circulation being set up in the South Pacific in the opposite direction to the hands of a watch. This warm water flowing southwards is called the **New South Wales or East Australian Current.** A large portion of the equatorial current is turned northwards and caused to circulate in the North Pacific in the same direction as the hands of a watch, a great Sargasso Sea occupying the centre. This current bears many points of resemblance to the Gulf Stream and is called the Kuro Siwo (Black Stream), or the **Japan Current.** It flows northward past the Philippine Islands and along the east coast of Japan where, similar to the Gulf Stream, it bifurcates, one of the forkings flowing into the Sea of Kamtschatka, the other crossing the Pacific, sweeping its immense volume of warm water past the Aleutian Islands and British Columbia, and finally merging into the great equatorial current near San Francisco. The stream is narrowest to the east of the Island of Formosa, where it is about 100 miles wide and its velocity rather more than three miles an hour, and it is estimated that it carries three times as much water as the Gulf Stream from the tropics to the north temperate zone.

The usual right handed system of circulation is not well developed in the northern part of the Indian Ocean on account of the influence of the monsoons and the presence of land where in other oceans water exists. This influence extends also to the southern part of the Indian Ocean, but is not sufficient to entirely stop the south equatorial current, which continues to flow towards the east coast of Africa, is divided by the Island of Madagascar, one portion flowing towards the Cape of Good Hope, the other flowing around the northern extremity of the island and southwards through the Mozambique Channel as the **Mozambique Current.** A large sandbank, the Agulhas Bank, has been formed off the Cape of Good Hope, and between this and the mainland the **Mozambique** or **Agulhas** or **Cape Current** flows. The volume of this current is greater than that of the Gulf Stream, its velocity off Delagoa Bay being said to be nearly six miles an hour. The current divides as it enters the South Atlantic, one portion flows northward along the western shores of Africa with the left handed vortex in this ocean; another portion returns to the Indian Ocean, meets the portion of the south equatorial current that flows southwards along the eastern shores of Madagascar, and sweeps with it as a stream of warm water past Amsterdam Island along West Australia into the current from which it came, thus completing the left-handed system of circulation, containing a Sargasso Sea in its centre.

So far the currents described have been currents of water warmer than the water on either side of them, and Dr. Haughton has shown that if the Gulf Stream carries more than one-twelfth of the sun's heat received by the torrid zone into the north temperate zone, then the currents of warm water we have here considered carry off more than half the heat received by the torrid zone from the sun and distribute it in the temperate zones.

But there must also be a flow of cold water from the frigid zones, and there are, therefore, cold currents. Two important **Polar Currents** may be traced in the North Atlantic, one flowing down Baffin's Bay and Davis Strait, and known as the **Labrador Current**, the other from the Arctic Ocean flows along the east coast of Greenland, and is known as the **Arctic Current.** The two streams meet off Cape Farewell and merge into the Gulf Stream near Newfoundland. These cold water streams leave the polar regions mainly as surface currents; on meeting the Gulf Stream their motion on the surface is impeded and they are forced to dip under that stream and continue their course as under-currents. In fact, a portion of the polar current dips down and pursues its course underneath the Gulf Stream into the Gulf of Mexico and the Caribbean Sea. That this under-current is a real and tangible current in the proper sense of the term, and not an imperceptible movement of the water, is proved by the fact that large icebergs, deeply immersed in it, are often carried southward with considerable velocity against both the force of the wind and the Gulf Stream.

The icebergs from the Arctic Ocean get melted by the warmer waters of the Gulf Stream, and the deposit of the material carried by them has doubtless produced the well known shoals off Newfoundland called the Newfoundland Banks. A branch of the cold polar current follows the American coast to about the latitude of New York, and its temperature is so distinctly lower than that of the Gulf Stream which hems it in, that it has been called a 'cold wall' of water.

Another cold stream of water is called the **Chili, Peruvian,** or **Humboldt's Current**, which runs from the Antarctic along the west coast of South America to mix with the great equatorial current in the South Pacific. A portion of this current sweeps round Cape Horn into the South Atlantic Ocean as the **Cape Horn Current.** A cold current also runs from the Antarctic along the south and west coasts of Australia. The various currents described in the foregoing are illustrated in Fig. 82.

From the facts we have given it will be seen that these regular and continuous movements of water termed surface currents only extend to a depth of about 500 fathoms. There are, however, deep sea currents which cannot be observed directly as the surface currents are, but which are made manifest by other means.

We have noted that the cause of the land and sea breezes lies in the fact that the daily variation in the temperature of the land is much more than the variation (about 1°) in the temperature of the surface of the sea.

In the equatorial regions the surface water has sometimes a temperature of 86° F, the normal temperature in the tropics being from 60° to 80°. This warm water, however, is only a thin film on the surface for at a depth of about ½ mile in the tropics it falls to 40°, and at the bottom it is ice cold. The surface temperature at the poles is about 30°.

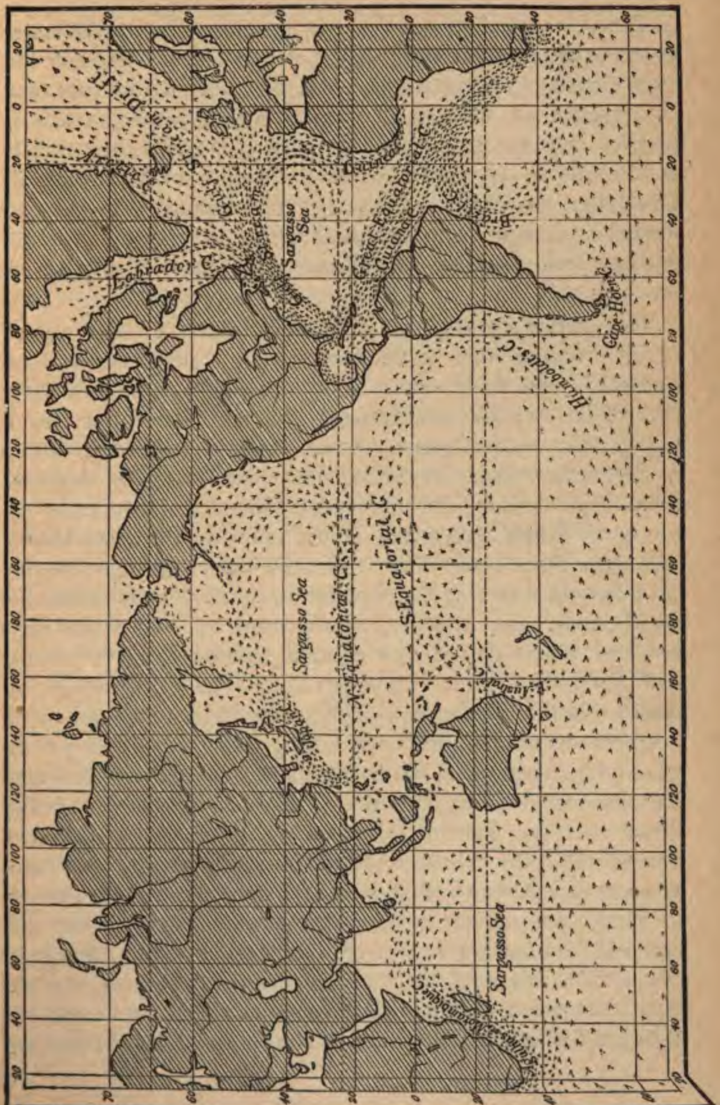


Fig. 82. Surface Currents of the Oceans.

The difference between the temperature of the surface water at the equator and at the poles is due to the fact that the sun only shines obliquely at the poles but is almost vertical over the equator all through the year. Again, since the sun is vertical over the tropic of Cancer in June and then travels southwards to be vertical over the tropic of Capricorn in December, the waters of the two hemispheres are subject to an annual variation. The amount, however, is very small at the equator and poles but in the temperate zones it may be as much as 10°.

The determinations of the temperature of the waters of the oceans that have been made during the various scientific expeditions similar to that of the 'Challenger,' show that below about 500 fathoms the temperature is never higher than forty degrees. Since, however, the temperature of the surface water at the equator may be eighty degrees, there is a tendency for the deeper water at the equator to be much hotter than water at the same depth at the poles; but observatons prove that is not the case, and therefore the cold bottom water at the equator must have come from the frigid zones. But the deep sea currents of cold water may not, and in fact do not, flow in equal volumes from the Arctic and Antarctic Oceans to the equator. The configuration of the land in the latter ocean offers every facility for the flow of deep sea currents towards the north, whereas the only places where the Arctic water can flow towards the south are between Europe and America, into the Atlantic and through Behring Strait into the Pacific. But sounding observations have demonstrated the existence of the 'telegraph plateau' between Europe and America, that is to say, a submarine ridge, rising to within 500 fathoms of the surface of the water, hence the creep of cold bottom water from the Arctic into the Atlantic is prevented at this point, and such water can only flow towards the equator through the Behring Strait and the narrow channels between Iceland and Labrador. The result of this obstruction is that the cold bottom water as far north as the 40th degree of latitude comes from the Antarctic Ocean. No better description of this could be found than that given by Captain, now Sir, George Nares, of the 'Challenger,' who, in his remarks on the temperature of the water in the North Atlantic between the equator and the 40th degree of latitude, says:—'Below the water immediately affected by the solar heat, which appears to be only the upper 60 or 80 fathoms, all the water in the North Atlantic, as far north as the 40th degree of latitude, is warmer than that at the same depth at the equator. . . . . There being water of a temperature of 32·4° at the equator, with warmer water at all stations north of it, proves conclusively that the cold water at the bottom of the Atlantic, as far as the Azores, 38° N., and Bay of Biscay, 46° N., equally with that at the equator, is derived from an Antarctic and not from an Arctic source; for if at the equator the water supplied from the southward retains its cold temperature to so great an extent, the bottom water of the North Atlantic, if supplied from the nearer Arctic Sea, should be at least as cold; but the temperature of the lowest stratum increases decidedly as we pass north, and completely cuts off the Arctic water found at the bottom of the Faroe Channel by the "Porcupine" from that we have discovered at the equator.

On the western side of the Atlantic, at all the stations south of the Bermuda and Azores lines, the bottom water is colder than on the east side, showing that the Antarctic cold current enters the North Atlantic and runs to the north-westward through the channels between St. Paul's Rocks and the Brazilian coast, and gradually expends itself as it circles round to the north-westward, in the same manner as the warm equatorial current does on the surface, considering that current as including the Gulf Stream, which it undoubtedly helps to produce.'

Many causes have been assigned to account for 'surface' and 'deep sea' currents. There is no doubt that the surface currents of the ocean form a system of circulation, the impelling cause of which is the prevailing winds of the entire globe, and when the effect of the wind in causing waves and obstructing tides is considered, it is not difficult to understand that a constant wind may drive the water of the oceans before it. In fact a working model, devised by Mr. A. W. Clayden, which may be seen in the western galleries of the South Kensington Museum, illustrates this exceedingly well. It consists of a model of the Atlantic, in which the seas are represented by the surface of some water over which a very light powder has been scattered A foot blower is attached, and when it is worked a gentle blast of air is delivered from a number of tubes in such a way as to set up a circulation of air resembling that of the atmosphere over the real ocean. These imitation prevalent winds act upon the water and create a system of currents resembling those of nature. The Gulf Stream may be seen issuing from the Gulf of Mexico, and the return current flowing eastwards between the two great equatorial currents, whilst the Labrador current flows from Baffin's Bay. The model is constructed so that portions of Central America are made removable, and when such a removal is made, the flow of the Gulf Stream is altered and fails to reach our shores.

But, although it is easy to understand this explanation of surface currents, it is not so easy to understand how the motion of deeper water is affected and the deep sea circulation is kept up by such a movement. This theory, however, is held by many eminent geographers, and Dr. Croll is foremost amongst its supporters. In the words of this eminent physicist, 'Much of the difficulty experienced in comprehending how under currents can be produced by the wind, or how an impulse imparted to the surface of the ocean can ever be transmitted to the bottom, results, to a considerable extent at least, from a slight deception of the imagination. The thing which impresses us most forcibly in regard to the ocean is its profound depth. An average depth of, say, three miles produces a strikin impression; but, if we could represent to the mind the vast area of the ocean as correctly as we can its depth, *shallowness* rather than *depth* would be the impression produced. We should call a sheet of water one hundred yards in diameter and one inch in depth a very *shallow* pool; in fact we should speak of it as simply a piece of ground covered with a thin layer of water. Yet such a thin layer of water would be a correct representation in miniature of the ocean: for the ocean in relation to its superficial area is as shallow as the pool of our illustration. In reference to such a pool or thin film of water, we have no difficulty in understanding how a disturbance on its surface would be transmitted to its bottom, and if we could form as accurate a sensible impression of the vast area of the ocean as we do of such a pool, all our difficulty in understanding how the impulses of the wind acting on the vast area of the ocean should communicate motion down to its bottom would disappear.'

A striking effect of a wind blowing in one direction is given by Dr. Croll in the following:—

The wind in Baffin's Bay and Davis Strait blows nearly always in one direction, viz., from the north. The tendency of this is to produce a surface current from the north down into the Atlantic, and to prevent or retard any surface current from the south. There is a warm current, however, flowing from the Atlantic, and when this meets the polar current it does not flow above it as might be expected from its being lighter, but is forced under it and pursues its course as an undercurrent warmer than the water above it.

The theory held by Dr. Carpenter to account for oceanic circulation is that the difference of temperature of the water at the equatorial and the polar seas, causes a difference of specific gravity between equatorial and polar water. The water at the equator, therefore, being lighter than the water in colder regions, stands at a somewhat higher level, and the gentle slope thus formed from the equator to the poles causes a general movement of the upper warm layers of the ocean from the equator to the poles, and a counter movement of the under cold layers from the poles towards the equator; the direction of the movement in each case being, of course, modified by the earth's rotation. Much can be said in support of this theory, for as long as the equator receives more heat from the sun than the poles, so long must tropical waters get expanded and specifically lighter than that in the temperate and frigid zones; so long must convection currents be set up, and warm surface currents and cold undercurrents exist.

The view is also held that because of the greater amount of evaporation at the tropics than at the poles, the tropical waters contain a greater proportion of dissolved salts, and are therefore specifically heavier than the polar waters; hence the surface water at the tropics, as it becomes heavier owing to the evaporation, sinks to the bottom and fresher and lighter water flows in, takes its place, and maintains equilibrium. The downward movement thus produces a circulation. A good example of this kind of circulation is afforded by the Mediterranean Sea, where less water falls than is evaporated from its surface. But the water of the Mediterranean does not increase in saltness, and therefore fresher water must flow into it from the surrounding ocean. In fact it has been proved that a surface current flows from the Atlantic Ocean through the Straits of Gibraltar into this sea, and that a very salt undercurrent flows outwards into the Atlantic. And this circulation is evidently due to the difference of specific gravity of the water in the enclosed sea and that of the ocean water which feeds it.

It appears most probable, therefore, that oceanic circulation is not caused only by the impulse of the wind, by the unequal heating of the waters on the globe, or by the diffe density arising from excessive and unequal evaporatio the result of all these causes.

GENERAL SUMMARY OF CHAPTER XV.

The Great Equatorial Current lies north and south of the belt of equatorial calms in latitude 6° N., and flows in a westward direction.

The Great Surface Current Systems caused by the breaking up of the equatorial currents are:—

(1.) The right-handed vortex in the North Atlantic Ocean called the Gulf Stream.

(2.) The left-handed vortex, of which the Brazil current is part, circulating in the South Atlantic Ocean.

(3.) A right-handed vortex in the North Pacific giving rise to the Japan current.

(4.) A left-handed vortex in the South Pacific, of which the New South Wales current forms a part.

(5.) A left-handed vortex in the South Indian Ocean, of which the Agulhas current forms a part.

The Best known Cold Surface Currents are:—

(1.) The Labrador and East Greenland currents flowing from the Arctic Ocean to the Atlantic.

(2.) Humboldt's current flowing from the Antarctic Ocean in a north-east direction to South America and into the south equatorial current of the Pacific.

The Temperature of the Surface Water of the Oceans varies considerably with the latitude, being about 80 degrees at the equator and 30 degrees at the poles.

The Temperature of Deep Ocean Water, that is, below a depth of 500 or 600 fathoms, varies from about 30 degrees to 40 degrees, and is practically uniform throughout the year.

The Theories of Oceanic Circulation are:—

(1.) That the impulse of the prevailing winds of the globe on the surface of the oceans produces a movement of the upper layers which is transmitted through the entire mass of water.

(2.) That the difference of temperature of equatorial and polar regions causes a difference of specific gravity, and a general movement of warmer and lighter surface water from the equator to the poles, and colder and heavier bottom water from the poles to the equator.

(3.) That unequal evaporation causes difference of saltness of the waters of the ocean, and therefore a difference of specific gravity, which produces a sinking of the denser water to a lower level and a movement of lighter and fresher surface water to take its place.

CHAPTER XVI.

CLIMATOLOGY.

THE general condition of the atmosphere at any locality—the variation in its temperature and amount of rainfall—the force and direction of prevalent winds and the amount of sunshine constitute the **climate** of that place. Hence climate is determined by observing the average weather during several years, and it may be hot or cold, wet or dry, mild or severe.

The average summer and winter temperatures of any particular locality vary very little from year to year, hence there is a practically constant difference between the temperatures at these two seasons, and this difference is called the **annual range of temperature.** The difference between the temperature in the day and night may be called the **diurnal range of temperature.**

At the equator the days and nights are equal throughout the year, hence the heat received from the sun in the day and that lost by radiation at night is practically constant and hence there is no marked difference between summer and winter temperatures, and no annual range of temperature.

In all other latitudes, however, the lengths of the days and nights vary; in the summer the days are the longer, in the winter the nights are the longer; the inequality in the lengths of the days and nights increases with the latitude and, generally speaking, the range of temperature also increases from the equator to the poles. Thus at Paramaribo, in Guiana, lat. 5° 35′ N., the range is only 4 degrees, whereas about the eightieth parallel of latitude it has been observed as much as 76 degrees.

Most of the United States has a range of 40°, and along the west coast of Great Britain it is 20°. By far the greater part of the globe, however, has a range less than 20°. It is less in the southern hemisphere than in the northern on account of the preponderance of sea-surface.

It is evident that climate must vary with the latitude, because latitude determines the amount of heat received from the sun. The sun's rays, for a reason given in a previous chapter, pierce the atmosphere at the equator vertically, hence little heat is absorbed. Away from the equator, however, the beams pass slantingly through this aerial envelope surrounding the earth, the heat is therefore dissipated and a less amount is received over the same extent of surface (Fig. 83) consequently, in

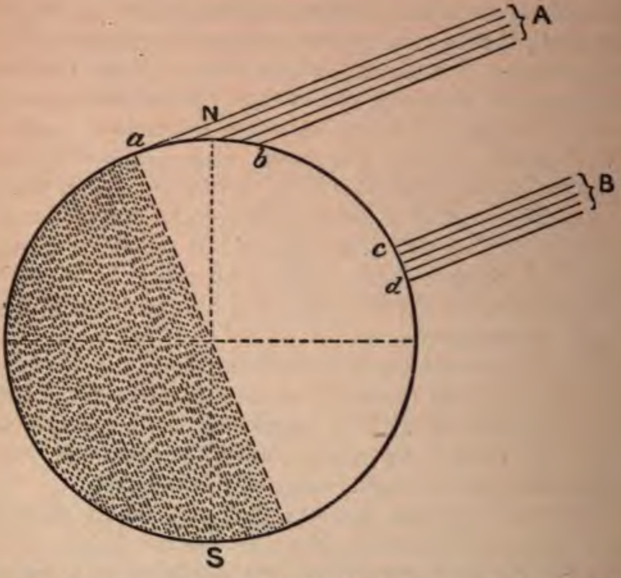


Fig. 83. Variation of Temperature with latitude. If A and B represent equal bundles of the sun's rays, it will be seen that their full effect is received between c and d, whilst at a and b the same amount of heat is spread over a larger surface.

proceeding from the equator to the poles, the temperature gets lower and the climate colder.

If the earth were entirely covered with water or consisted entirely of land, then the climate of any part would be determined by its latitude, and therefore all places having the same latitude would have the same climate. But this is not the case, and the following table shows that places having the same latitude may have very different climates, as evidenced by a great difference in their range of temperature.

	Latitude	Average Summer Temperature	Average Winter Temperature	Range
Lisbon	39°	71°	52°	19°
Pekin	40	81	27	54
Vienna	48	70	29	41
London	51	64	37	27
Edinburgh	56	57	38	19
Moscow	56	64	15	49
Aberdeen	57	59	39	20
Nain (Labrador) ...	57	47	0	47
Bergen (Norway) ...	60	58	36	22
Yakutsk (Siberia)...	62	66	−45	111
Boothia Felix ...	70	38	−28	66
Mageröe	71	44	24	20
Melville Island ...	75	37	−32	69
Spitzbergen	78	45	5	40

It is evident therefore that other causes besides latitude must affect the climate of a place, and also that places having the same average yearly temperature have not also the same climate. Thus, London and Vienna have nearly the same average temperature but very differerent ranges of temperature.

The first of these modifying causes is the altitude of the place, that is, its height above sea level. It has been pointed out that even in the torrid zone the highest mountain peaks are always capped with snow, owing to their being above the limit of perpetual snow or snow-line; hence it is easy to understand that in ascending a mountain from the level of the sea the same change of climate is experienced as in journeying from the equator towards the poles—in fact, an elevation of about 300 feet is marked by a fall of one degree, that is, about the same diminution in temperature as is experienced in moving one degree of latitude towards the poles. This fact is taken advantage of by Europeans in India, who recruit their health by retiring to the hills during the hot season; for by ascending some 3,000 feet on the Himalayas and Neilgherries a bracing atmosphere is obtained.

Similarly, places situated on table-lands have a lower average temperature than other localities having the same latitude but not so elevated, but at the same time the range of temperature in such elevated stations is greater than at a lower level. Thus, Madrid has nearly the same latitude as Lisbon, but, owing to its being situated at a much higher level, its range is nearly twice as great.

Quito, situated 9,000 feet above sea level, and many other places on the Andes in South America, enjoy quite temperate climates on account of their elevated position.

It may seem strange that there should be a diminution of temperature as we ascend in the atmosphere, that is, as we approach the sun, for the amount of approach is far too small to produce any effect. Now, as a matter of fact, the atmosphere derives its heat from the radiation of the heat received by the earth, by direct contact with the heated surface, and by the water-vapour absorbing a portion of the solar radiation. Professor Tyndall showed some years ago that the aqueous vapour in the atmosphere acts like a blanket and prevents the dissipation into space of the dark heat rays radiated from the earth's surface. In 1885 Professor Langley showed that the atmosphere had an enormous effect in stopping the rays the sun and behaved like a roof of coloured glass aroun earth. It is evident, therefore, that the amount of absor must vary with the thickness of atmosphere traversed and its density. On the tops of mountains the atmosphere is much less dense than at sea level, and it therefore contains less moisture. The result is a diminution of the power to absorb the heat radiated by the earth or those rays coming directly from the sun. And being at a greater distance from the earth's surface it receives less heat by contact; and finally, rapid radiation into space occurs on account of the absence of the water-vapour present at a less elevation.

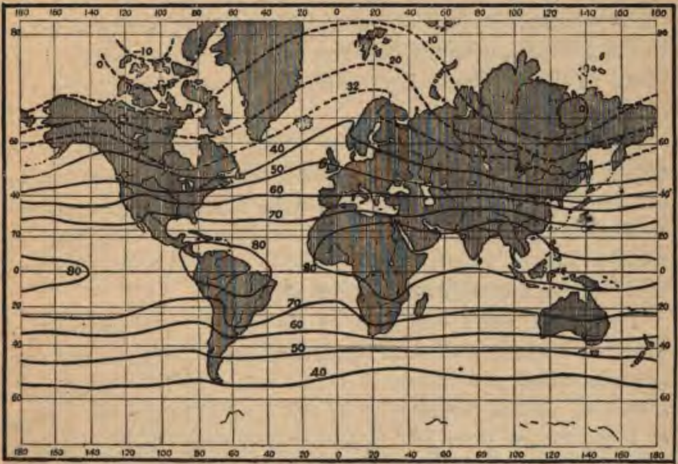


Fig. 84. Iso-Thermal lines showing places that have the same average yearly temperature.

The situation of a place with respect to the sea is of considerable importance in determining its climate. It has been pointed out that all water surfaces tend to equalize temperatures, that is, tend to render a climate less hot in summer and less cold in winter. Hence in a district near a water surface the range of temperature is small and the climate is temperate, or, as it is more often termed, oceanic or **insular**. A truly oceanic climate occurs on such small islands as are found in the Pacific, where the temperature only varies about five or six degrees throughout the year. An insular climate is exemplified by Great Britain and Australia, where the range of temperature is 20°.

The influence of water surfaces upon climate is exemplified in Fig. 84, which gives the **iso-thermal lines**, or lines of equal temperature. These lines join those places that have the same average yearly temperature. It will be seen that in the southern hemisphere the preponderance of water surface causes the iso-thermals to be distributed with much regularity according to the latitude, whereas the irregular distribution of land and water in the northern hemisphere causes the lines to be very irregularly distributed.

In contradistinction to places whose climate is tempered by water, there are large tracts of land where no such modifying influence exists, where there is a wide range of temperature—a climate of extremes. These localities are therefore extremely hot in summer and severely cold in winter and are said to have a **continental climate**.

There are many examples of the effect of large tracts of water in making a climate insular, whereas places in the same latitude which are deprived of this influence have continental climates. Thus, the interior of the United States has a range of temperature from 30° to 60° greater than places in corresponding latitudes on the Pacific coast, and although Moscow has the same latitude as Edinburgh the average difference between the summer and winter temperatures at the latter place is 19 degrees and at the former 49 degrees.

Ocean currents also exert a considerable influence on climate, a cold current lowering the temperature of the coast near which it passes, a warm current raising it. Hence the east coasts of South America, Africa and Australia, towards which the warm equatorial current flows, are warmer than the west coasts. In the northern continents, however, the west coasts are much warmer than the east coasts on account of the cold currents which run along the east coast from the Arctic Ocean. Thus the cold Labrador current lowers the temperature of Newfoundland and New York and other places on the east coast of North America. Places on the opposite side of the Atlantic in the same latitudes have much warmer climates because of the influence of the warm Gulf Stream drift; for, although the Gulf Stream proper does not exist further north than the latitude of Newfoundland, the warm waters drifted by it affect the climate of the whole of north-west Europe. The winter temperature of London due to its position on the globe is about 17°, and that of Shetland 3°. On account of the Gulf Stream, however, the former has a mean winter temperature of 37° and the latter of 39°. The influence of the stream is also well marked by the mild climate of the Faröe Islands, situated in latitude 62°, that is, several hundred miles north of Scotland; and Dr. Haughton concludes that 'The effect of the Gulf Stream upon the climate of Spitzbergen at present is to raise its mean annual temperature 11·5° Fahr.' Hence if any breaking up of land should occur to prevent the flow of the warm water of this stream into the North Sea it is evident that the climate of Norway and the British Islands would be affected.

It has been shown that ocean currents have the same direction as the prevailing winds, hence climate is affected not only by the warm or cold water which washes the coast but much more by the influence of the winds which arrive with it. The air lying on any surface tends to acquire the temperature of the surface; air lying on water surfaces contains more moisture than air in contact with land, hence, a wind is hot or cold, moist or dry, according to the temperature and nature of the surface from which it blows. A wind blowing from a warm water surface to a colder region has its moisture condensed, but the condensation of vapour entails a giving up of latent heat, and hence the temperature of the place receiving the rainfall is raised. Conversely, a cold current tends to prevent precipitation, that is, its moisture is not deposited when it reaches a warmer region—in fact, more water may be absorbed. Thus not only is there no latent heat given up, but the transformation of water into vapour takes up a certain amount of heat. Both causes, therefore, tend to lower the temperature of the locality towards which the cold wind blows. The winds that blow from the interior of continents are liable to much greater extremes of temperature than the sea breezes, being very hot in summer and very cold in winter.

In England we know that an easterly wind is a cold wind, whilst a westerly wind is warm and moist. This is because in the former case the wind blows from higher latitudes, and reaches us as a north-east wind in consequence of the earth's rotation. Winds having a westerly direction are warm for two reasons—firstly, they blow from the equator, and, secondly, they contain a lot of moisture absorbed from the Atlantic Ocean, which, falling to the earth as rain, liberates latent heat and raises the temperature of the air. Thus the west coasts of Europe and North America are rendered milder and moister by these south-west winds than corresponding latitudes inland and on the east coast. On the east coasts of Asia and America, where a cold north-east wind is prevalent, a great difference exists between the summer and winter temperatures.

Another cause affecting climate is the aspect or the direction of the slope of a district. The land which slopes towards the equator receives the sun's rays less obliquely than land sloping towards the poles. If we conceive a hill in our hemisphere to have a southward inclination of 45° in a place where the sun reaches an altitude of 45°, then the sun's rays will fall vertically upon the hill at mid-day, whereas if no such inclination existed they would strike the land obliquely. If, however, the hill had a northward inclination of the same amount the sun's rays would only graze along the surface when our luminary reached an altitude of 45° (Fig. 85). Hence it is evident that in the northern hemisphere the south sides of hills are warmer than the north sides; in the southern hemisphere, however, hills with a northward inclination are sloping towards the equator, hence the northern sides of such hills are warmer than the southern. Thus the height of the snow line may lie at a different level on the north and south sides of the same hills and mountains. In North America most of the land north of latitude 50° slopes towards the poles; in Europe, however, only a small portion of the land has this northward slope, and this lies north of latitude 60°; this is one of the reasons why the climates of North America and Europe, even on the same parallels of latitude, are so different. A striking example of the influence of slope on climate is afforded in Asia. From the table-land of Central Asia there is a general slope southward and northward. On the southern side tropical vegetation flourishes even at a height of 5,000 feet; but on the northern side the climate is considerably colder until Siberia is reached, where intense cold prevails all the year at places situated no further north than Edinburgh. Similarly, the southern side of the Alps has a magnificent climate, whilst the northern side is covered with ice.

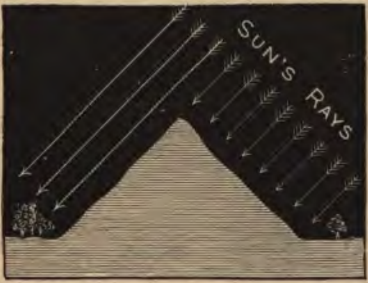


Fig. 85. Influence of Aspect on Climate.

It is evident from what has been previously said that the direction and height of mountain ranges affect climate because they cause the condensation of moisture. Hence in the case of a mountain running at right angles to prevailing winds the side which the wind first reaches, that is, the windward side, will have a moister and warmer climate than the opposite or leeward side.

It has been pointed out in a previous chapter that the west coast of Great Britain has more rainfall than the east coast for this reason. Similarly, the Andes running along the west coast of South America intercept the moist trade winds from the Atlantic, the result being that the slopes on the Pacific side are dry and rainless.

The Alps run nearly parallel to the direction of the prevalent wind, hence they have no very well marked wet and dry sides.

Mountains may also shelter localities from wind and thus affect the climate. The mountains of Scandinavia and Lapland protect the north of Europe from the cold winds that blow from the Arctic region; no such influence exists, however, to modify the climate of Russia and hence this is another reason why the climate there is much colder than in many other places in corresponding latitudes.

The character of the land surface has a very important bearing on climate. Rocky or sandy soils are subject to great extremes of temperature; they readily absorb the sun's heat and become extremely hot during the day and rapidly radiate the heat into space and thus become ice-cold during the night. The Sahara Desert is an example of a region having an extreme range of temperature.

Wet marshy land lowers the average annual temperature, hence the effect of draining the marsh is to raise the average temperature—in fact, the increase in temperature due to drainage in Great Britain during the last hundred years is from two to three degrees. Forests modify the heat of the sun during the day and prevent very rapid radiation during the night, and thus tend to equalise the temperature; but they have also a cooling effect, being often associated with marshy land, for the trees act as condensers of the moisture in the atmosphere, and the rain that falls cannot flow freely off the land but accumulates in low-lying parts; the air in contact with it is cooled and, there being no free circulation, it remains cool. As forests are cleared however, and the amount of uncultivated land is decreased, the climate is made warmer, because the sun's rays are no longer cut off from the soil, and there is a freer circulation of air. The marshy region becomes a land covered with vegetation and traversed by a few rivers, and the climate is rendered drier because the condensers of atmospheric moisture have been demolished. The clearing of forest land, however, may be carried too far, and a region luxuriant with vegetation rendered barren through lack of rain.

GENERAL SUMMARY OF CHAPTER XVI.

The Annual Range of Temperature is the difference between the *average* temperatures of summer and winter.

The Climate of a Place is its average weather conditions and is mainly dependent upon :—

(1) The mean annual temperature and the range of temperature.

(2) The mean annual rainfall and its distribution throughout the year.

(3) The amount of bright sunshine.

Some Causes affecting Climate and the nature of the influence are as follow :—

(1) Latitude, or distance from the equator, the temperature decreasing as the latitude increases.

(2) Elevation, or height above sea level, the temperature decreasing as the elevation increases.

(3) Distance from the sea or any large tract of water, the range of temperature being diminished by their presence.

(4) Distance from large tracts of land, the range of temperature being increased by their presence.

(5) Ocean Currents and Prevailing Winds increase or diminish the temperature according as they flow from the equator or from the poles.

(6) Aspect or general slope of the land, that which slopes towards the equator receiving more of the sun's rays than that which slopes towards the poles.

(7) Height and direction of mountain ranges. The effect varies according to whether the chain is parallel or inclined to the direction of the prevailing winds.

(8) The nature of the soil. Sandy and rocky soils increase the temperature; marshy and forest land decrease it.

(9) Drainage and cultivation of the land increase the temperature and dryness.

A Locality has an Insular Climate when its annual range of temperature is small, and **a Continental Climate** when its annual range of temperature is large.

CHAPTER XVII.

PLANTS AND ANIMALS.

The living things upon the earth may be divided into two great classes or kingdoms—the animal and the vegetable kingdoms. Such a classification, however, is too broad, so each of them is divided into groups and species, the members of each of which possess some common characteristic.

Investigations have shown that many animals and plants resemble each other even when they are not exactly alike—*e.g.*, there are many kinds of dogs, but all of them possess certain common characteristics; again, many kinds of apples are known, but all of them are similar.

It has been pointed out in a previous chapter that animals evolve or breathe out more carbon dioxide (CO_2) and water (H_2O), and less oxygen than they inspire or breathe in. From this fact it is evident that substances are constantly being lost, and that some action must exist to keep up the supply, or animals would gradually dwindle away. The things required besides fresh air are water and food. A necessary part of the food is a compound substance called *protein*, containing carbon, oxygen, hydrogen and nitrogen. Now plants have the power of transforming carbon, oxygen, hydrogen and nitrogen into the compound substances required by them to live; but animals have not the power of manufacturing these compounds, although they also require them to live; they obtain the necessary protein however by feeding upon the plants, hence animals require vegetation in order to live. Plants obtain a great amount of food from the soil, utilizing the nitrates, sulphates, phosphates and silicates which occur in it. Cabbages and turnips contain much sulphur; grasses and cereal plants, such as wheat, rye, oats and barley, require much silica, this being the compound which gives stiffness to their stalks and also to canes and bamboos.

Before proceeding to the question of the distribution of life upon the globe it will be best to give a few definitions. To begin with, all animals possessing a flexible backbone and an internal framework or skeleton, a true brain, nerves, and a spinal cord are called **vertebrata.**

The classes of this division are:—

1. Fishes.
2. Amphibians (frogs, toads, newts, etc.).
3. Reptiles (snakes, lizards, crocodiles, etc.).
4. Birds.
5. Mammals, *i.e.*, animals which feed their young from the breast and produce them in a living state.

The animals called **mammals** or mammalia are divided into other groups or orders, thus:—

Name of order.	Meaning of name.	Examples.
Marsupialia	Pouched	Kangaroo, opossum.
Edentata	Toothless	Sloth, ant-eater.
Pachydermata	Thick-skinned	Elephant, horse.
Ruminantia	Cud-chewers	Ox, sheep, camel.
Rodentia	Gnawers	Rat, hare, beaver.
Carnivora	Flesh-eaters	Whale, bat, tiger.
Quadrumana	Four-handed	Monkey, ape.
Bimana	Two-handed	Man.

The other classes of vertebrate animals are similarly divided into sub-groups or orders.

The following are the three remaining important divisions of the animal kingdom :—

DIVISION II.

Name.	Meaning of name.	Examples.
Articulata.	Jointed animals, that is, possessing a jointed covering corresponding to the internal skeleton of vertebrata.	Worms and leeches, centipedes, crabs and lobsters, spiders, bees and other insects.

DIVISION III.

Mollusca.	Pulpy animals.	Snails, limpets, oysters, mussels, jelly-fish.

DIVISION IV.

Radiata	Rayed animals.	Star-fishes, sea-urchins.

Plants are divided into two great classes—**Cryptogams**, or plants destitute of flowers (*e.g.*, ferns, mosses, lichens and fungi), and **Phanerogams,** or flowering plants.

The reproduction of cryptogamic plants takes place indifferently from any part of the surface; sometimes, as in the case of ferns, spores grow in clusters on the under side of the leaf; sometimes, as in the case of fungi, from spores within a part of the plant, which, when broken off, will reproduce. Cryptogamic plants are therefore termed **Acotyledons,** that is, without a cotyledon or seed-leaf. Phanerogamic plants are subdivided thus:—

Group.	Example.	Characteristics.
Monocotyledons	Rushes & grasses Cereals or grain plants Lilies Palms	Grow from a single lobe or cotyledon in the seed. Absence of a distinct pith.
Dicotyledons	Garden vegetables Fruit trees Woody plants	Grow from a double lobe or cotyledon in the seed. Possess a central pith and an outside bark. Increase their stems by a series of concentric rings.

Since the **Fauna**, that is, the various animals belonging to a country, is dependent in amount to a great extent upon the **Flora**, that is, the assemblage of plants, the geographical distribution of the latter is described first.

The following table exhibits the effect of latitude and elevation upon the character of the plants of a region, and it will be seen that, starting from the base of a mountain at the equator, the various species may be encountered either by journeying towards the poles or by ascending the mountain.

Latitude.	Names of zones.	Elevation in feet at equator.	Characteristic plants.
0°–15°	Equatorial	Sea level—2,000	Palms and bananas.
15 –23½	Tropical	2,000—4,000	Figs and tree-ferns.

Latitude.	Names of zones.	Elevation in feet at equator.	Characteristic plants.
23½-34	Sub-tropical	4,000—6,000	Myrtles, laurels, acacias and trees with thick shining leaves.
34 -45	Warm-temperate	6,000—8,000	Evergreen trees.
45 -58	Cold-temperate	8,000—10,500	Trees with deciduous foliage, *i.e.*, trees which lose their leaves on the approach of winter.
58 -66½	Sub-arctic	10,500—12,500	Coniferae — an order of plants which, like the fir, pine, cypress, and beech, bear cones or tops in which the seeds are contained.
66½-72	Arctic	12,500—14,800	Mosses and lichens.
72 -90	Polar	14,800-snow-line	Alpine herbs.

It is not easy to express many details in tabular form, so the following supplementary description is given. In the Torrid Zone a rank and luxuriant vegetation prevails. There we find palms, bananas, and other characteristic trees, whilst climbing vines entwine and interlace with enormous tree ferns and tree grasses.

Lions, tigers, elephants, crocodiles, and many animals of a similar character, beautiful birds and huge serpents, and hosts of brilliant butterflies, moths and beetles are also met with.

There is no marked difference between the summer and winter temperatures and therefore plants are in bloom throughout the year.

In passing from the equatorial regions to more temperate zones a change takes place not only in the nature but also in the amount of animal and vegetable creation. The forests become less dense and the undergrowth which renders equatorial ones impassable to man is considerably diminished. In this zone the oak, elm, ash and beech and other deciduous trees are found. A marked difference also exists between the flowers that bloom at different seasons of the year, primroses, snowdrops and violets being found in the spring, geraniums and wild roses in the summer.

The animals that live in the temperate zone differ widely from those found in equatorial regions ; bears and wolves inhabit the hills; foxes, otters, badgers and rats the lower ground, whilst the birds, larks, thrushes, and sparrows, like the other animals in this zone, are much less gorgeously coloured than their equatorial brothers. Some of the animals living in the temperate zone pass the colder months of the year in a state of torpor, others take on a thicker covering of fur, whilst others move into warmer regions in search of food.

On approaching the polar regions life becomes still less abundant, the fir, birch, pine, spruce and willow being the trees last met with; these finally disappear, however, and the only vegetation consists of mosses, lichens, stunted shrubs and a few hardy flowering plants which can be covered with snow and thus preserved during the cold winter months. The animals of these regions are scarce inland; and are mainly white bears and foxes, reindeer and ermines; in the seas are found walruses and whales, and on the coasts flocks of white feathered birds, all of them constituted so as to withstand the cold climate. From the foregoing it will be seen that there is gradual diminution in luxuriance of animal and vegetable life from the equator to the poles, thus demonstrating that warmth is favourable to their development.

It is easy to understand that the effect due to altitude differs with the latitude, and that local circumstances may modify it, *e.g.*, in the northern Alps the upper limit of the grape vine is 1,600 feet; in the central Alps is 2,000 feet; and in the groups of Monte Rosa and Mont Blanc it ascends to nearly 3,000 feet.

The influence of elevation on animal life is also well demonstrated in Europe. On the mountains the bear, goat and eagle find a home, whilst in the warmer plains occur rabbits and moles, larks and thrushes. The kinds of plants and animals of the Old and New World are also different in many districts, even where the climates are similar. Thus the lions, tigers and leopards in the Old World are replaced by pumas and jaguars in the New World, apes and baboons by monkeys and marmosets, vultures by the condor, whilst plants of the cinchona family give us coffee in the Old World and quinine and ipecacuanha in the New World.

By observing and comparing the fauna in different parts of the earth naturalists have been enabled to divide the land into six great regions, each characterised by the abundance of certain kinds of animals, which, if they are found at all in other regions are not nearly so plentiful. These regions are as follows:—

The Palæarctic or Europasian Region includes all Europe, all Africa and Arabia north of the tropic of Cancer, all Asia except that part south of the Himalayas and Southern China, and Persia to the Indus. The boundary line is thus a natural one and consists of the Sahara and Arabian deserts, the Arabian Sea, Solyman range, the Hindoo Koosh, the Himalayas and the Nanling range.

The nature of the fauna of this region is tabulated below, and although botanists generally divide the vegetation of the earth into twenty-four regions, the distribution of the two are so related to each other that the nature of the flora is also given.

Europasian Fauna.

- Antelopes
- Wild Boars
- Bears
- Swine
- Yaks
- Goats
- Wild Sheep
- Camels
- Badgers
- Hedgehogs
- Otters
- Hares
- Dormice
- Starlings
- Magpies
- Nightingales
- Partridges
- Pheasants
- Eagles
- Hawks
- Vultures
- etc.

Europasian Flora.

- Poplars
- Willows
- Hazels
- Oaks
- Yews
- Pines
- Elms
- Ashs
- Maple
- Sycamore
- Horse-chestnut
- Cereals
- Figs
- Olives
- Oranges
- Grape Vine
- Almonds
- Roses
- Alder-fens
- Heather
- etc.

Much of the Arctic portion of this region and thousands of square miles in Siberia are covered with mosses and thin, black, grey or yellow crusts of vegetable life called lichens. Lands covered with mosses are called **Moist Tundras,** lands covered with lichens are known as **Dry Tundras.**

In passing from the northern to the southern portion the white bear is replaced by the brown one and Arctic hares and foxes by those met in our latitude.

The Nearctic or North American Region is the next great zoological division of the globe, and consists of all Temperate and Arctic North America with Greenland.

The nature of the fauna and flora of this region are exhibited in the following table :—

North American Fauna.

Moose-Elks
Prong-horned Antelope
Skunks
Ragoons
Puma or Panther
Bears
Bisons
Lynxes
Wolves
Marmots
Flying Squirrels
Walruses
Seals
Beavers
Musk-Ox
Big-horn Sheep
Otter
One kind of Opossum
Sewellel
Tree Porcupines
Prairie Dogs
Musk Rats
Jumping Mouse
Crested Partridges
Wild Turkeys
Blue Jays
Hang Nests
Humming Birds
Mocking Birds
etc.

North American Flora.

Sequoia Pines
Douglas Pines
Golden Rods
Maize
Oaks
Maples
Poplars
Walnuts
Mahogany
Cedars

Imported from other Regions.

Sugar Cane
Yucca
Cocoa-nut
Cotton
Tobacco
Rice
Potato
Cereals

That a great resemblance exists between the fauna and the flora of these two regions will be seen from the following table, which shows those forms of life common to both.

Fauna common to Palæarctic and Nearctic Regions.	Flora common to Palæarctic and Nearctic Regions.
Bears	Pines
Elks	Larches
Deer	Spruces
Buffaloes	Firs
Wolves	Hemlocks
Foxes	Cedars
Weasels	Oaks
Wild Cats	Chestnuts
Squirrels	Beeches
Moles	The Ash
Marmots	The Elm
Hares	Sycamore
Eagles	Walnut
Owls	Maple
Crows	Gentians
Thrushes	Rushes
Hawks	Primroses
Wrens	Birches
Tits	Willows
Finches	Saxifrages
etc.	Cereals
	etc.

Although this resemblance exists between the fauna and the flora of the two regions, there are many reasons why they should be considered as separate. It must also not be concluded that the plants are exactly alike, even when they are tabulated as common, for the oak, beech, elm, ash and maple are of a different species in the two regions. Another point in which the forests of North America differ from those of Europe is that they are mixed, all kinds of trees growing together. In Europe, however, as is generally known, the forests are almost always made up of one or two kinds of trees.

In Europe the cereal grasses vary somewhat with the latitude; barley is cultivated most extensively in the northern parts, rye and oats somewhat further south, and still further south wheat flourishes. The orange and grape vine only flourish in the most sunny localities and where the range of temperature is not great, hence neither are cultivated in the North American region with much success.

The Neotropical or South American Region comprises the whole of South America and the adjacent islands, West Indies, and the tropical parts of North America and Mexico.

The following fauna and flora are characteristic of this region:—

South American Fauna.

- South American Monkeys
- Marmosets
- Leaf-nosed and blood-sucking Bats
- Chinchillas and Viscachas
- Opossums
- Armadilloes
- Sloths
- Ant-Eaters
- Tapirs
- Cavies and Agoutis
- Deer
- Llamas or Alpacas
- Condors
- American Ostriches
- Jacamars

South American Flora.

- Mahogany
- Logwood
- Rosewood
- Cinchona (or Peruvian bark)
- India-rubber plant.
- 'Bean' trees
- Mangroves
- Palms
- Numerous Laurels
- Cacti
- Orchids
- Bananas
- Tree Ferns
- Mimosas
- Cayenne Pepper

South American Fauna.

Toucans
Macaws
Boa Constrictors
Alligators
etc.

South American Flora.

Potato
Cacao
etc.

This region produces the most luxuriant flora in the world and the fauna is more varied than that of any other. It is poor in large quadrupeds and hoofed animals as compared with Africa and Asia, but almost all the animals differ from those of the Old World, whilst many of the Old World families are entirely absent. The monkeys are small and slender with long tails, and none of the large kind are found; indeed, the mammalia and the birds are all of a low type.

Vast intensely-hot plains called **Llanos** occur on the Upper Orinoco, covered with tall grasses and almost bare of trees. Similar plains, or **Pampas**, occur on the La Plata; these have even a less amount of vegetation but are sometimes densely covered with enormous thistles.

The Ethiopian or African Region includes Central and Southern Africa, Madagascar and the adjacent islands.

The following are the fauna and flora characteristic of this region:—

African Fauna.

Aard Wolves
Hippopotami
Rhinoceroses
African Elephants
Giraffes
Zebras
Quaggas

African Flora.

Fig Marigolds
Carrion-scented Stapelias
Aloes
Pelargoniums
Oil Palms
Baobabs
Euphorbias

African Fauna.

Wild Asses
Cape Ant-Eaters
Aye-ayes
Madagascar Hedgehogs
Lions
Leopards
Hyenas
Antelopes
Jackals
Civet Cats
Gorillas
Chimpanzees
Baboons
Flamingos
Chameleons
Crocodiles
Guinea Fowls
Vulture Crows
Crested Tourocos
Conies
etc.

African Flora.

Zamias
Bignonias
Tamarinds
Maize
Sorghum
Pumpkins
Yams
Sweet-Potato
Cape Heaths
Cape Bulbs
Geraniums
Cereals
Bananas
Coffee
Sedges
etc.

It should be observed that such widely spread animals as the bear, deer, sheep, goats, true ox, true pig and moles are absent from this region.

On the other hand, the hippopotamus, giraffe, zebra, quagga, and wild ass are in Africa, but in no other regions on our globe. There are also more than fifty species of antelopes. The African monkeys are larger and more highly organised than in any other part; in fact, both the fauna and flora show a most highly organised and complicated state of development.

The Oriental Region comprises Asia south and east of the Himalayas, southern China, and the Malay Archipelago as far as the Philippines, Borneo and Java.

This region is poorer in truly characteristic mammals than the others, but rich in birds and insects. Many of the animals are related to those found in the African region, while representatives of all important Europasian families except dormice are met with.

The following table shows the characteristic fauna and flora:—

Oriental Fauna.

Tigers
Ounces
Hyenas
Jackals
Elephants
Rhinoceroses
Bears
Deer
Wild Cattle
Wild Hogs
Tapirs
Flying Lemurs
Ourang-outang
Long-armed Monkeys
Squirrels
Mice
Long-tailed Parrots
Peacocks
Babbling Thrushes
Green Bulbuls
Numerous Pheasants
Hornbills
Trogons
Crocodiles
Tree Snakes
Cobras
etc.

Oriental Flora.

Ginger
Arrowroot
Bananas
Cocoa-Nuts
Screw-Pines
Yams
Bamboo
Rice
Gourds
Pitcher Plants
Wood-Oil Trees
Mangoes
Coffee Tree
Mangroves
Teak
Toon
Ebony
Sal
Cycads
Satin Wood
Sandal Wood
Iron Wood
Bignonias
Hemp
etc.

Asia has a greater number of Carnivora or flesh eating animals than Africa, and differs also in having bears and a few species of deer. The birds of this region are singularly beautiful, varied, and abundant. The flora has few distinctive features.

The Australian Region includes Australia, New Zealand, Papua, Gilolo, Celebes and the East Indian Archipelago as far west as the Straits of Bali or Lombok, and all the tropical islands of the Pacific.

The following are the characteristic fauna and flora of this region:—

Characteristic
Australian Fauna.

- Kangaroos
- Native Cats
- Native Ant-eaters
- Bandicoots
- Phalangers
- Wombats
- Duck-billed Platypus
- Bats
- Mice
- Australian Hedgehog
- Bird-of-Paradise
- Honeysuckers
- Lyre-birds
- Emus
- Cassowaries
- Paroquets
- Cockatoos
- Brush Turkeys
- etc.

Characteristic
Australian Flora.

- Beef-wood trees
- Gum-trees
- Acacias
- Pandanus
- Pines
- Cabbage-palms
- Figs
- Nutmeg
- Sandalwood
- Heath-like epacris
- Tree ferns
- Bananas
- Cycads
- Cocoa-nut Palm
- Bread Fruit
- Tacca
- etc.

Most of the animals peculiar to this region are marsupials. The only animal of this character out of Australia is the opossum of America.

Few of the trees of this region bear any fruit, although trees and shrubs with dull olive foliage abound. The eucalyptus, or gum-tree, and a few others, have leaves whose edges point to the sky. The six great regions into which animal life has been divided are shown in Fig. 86.

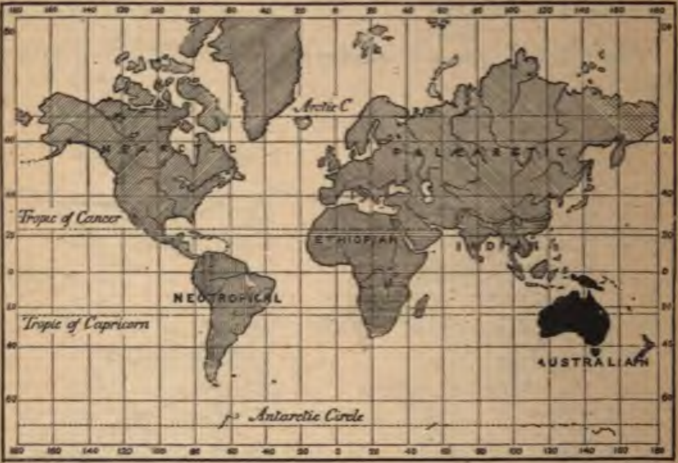


Fig. 86. Geographical distribution of Animals.

It is evident from the many examples given that some cause or causes must exist to limit the range of the animals and plants upon the earth. To quote Dr. A. R. Wallace, the eminent naturalist and friend of the late Charles Darwin:—

'Deer have a wonderfully wide range over the whole of Europe, Asia and South America; yet in Africa south of the great desert there are none. Bears range over the whole of Europe, Asia and North America, and true pigs of the genus *Sus* over all Europe and Asia and as far as New Guinea; yet both bears and pigs, like deer, are absent from Tropical and South Africa . . . . Various important groups of animals are distributed in a way not easy to explain. The anthropoid apes in West Africa and Borneo; the tapirs in Malaya and South America; the camel tribe in the deserts of Asia and the Andes; the trogons in South America and Tropical Asia, with one species in Africa; the marsupials in Australia and America are examples.'

The main causes affecting the distribution, however, may be expounded. The tables given in the preceding pages afford sufficient evidence of the action of climate upon distribution. A warm and moist climate is favourable to plant life, a hot and dry one to the animal kingdom.

A plant may be transported and will grow in a place distant from its native country, provided the two climates are similar. Examples of the fact that similarity of climate is favourable to the production of similar species are furnished by the beeches of Japan and the Straits of Magdalen, and by the heaths of western Europe and the Cape of Good Hope. In fact, difference of climate is the chief cause regulating the distribution of flora. The Sahara Desert separates the flora of tropical Africa from that of the Mediterranean region and the forest region of equatorial America is an effectual barrier to the migration of the native plants of the grassy plains of Brazil and Venezuela, whilst seas and oceans present an insurmountable obstacle to seed transportation.

Mountain chains and the existence of other plants and animals also aid in determining the nature of the flora of a region.

The distribution of animals on the earth's surface is not simply dependent on climate as was once supposed. From the tables we have given it will be seen that the animal life of Africa and South America are very different, although their climates are similar and both are covered with luxuriant forests.

Again, South Africa and Australia have climates wonderfully similar, yet there is a wide difference in the character of the animals. Similarly, no crows are found in South America although they inhabit every other part of the world. Antelopes are confined to Africa and Asia, sloths to South America, true lemurs to Madagascar and the bird-of-paradise to New Guinea.

The migration of the characteristic animals of a region to other parts of the earth may be prevented by many means. Deep seas and oceans are effectual preventatives. Rivers, vegetation and temperature may form equally effective barriers to migration, and in some cases the animals on opposite sides of a mountain chain are of different character. Thus, all the mammalia, birds and insects on the two sides of the Andes and Rocky Mountains are of distinct species, and to a less extent the Andes and Pyrenees effect the same separation.

Many of the largest mammalia are able to roam over whole continents and are hardly stopped by any physical barrier. Examples of this kind are the elephant, tiger, rhinoceros and lion. Other groups of animals are more limited in their migrations, *e.g.*, apes, lemurs, and many monkeys, squirrels, opossums, and sloths. Similarly, deserts or an open country are essential to such animals as the camel, hare, zebra, giraffe, and many of the antelopes. They cannot exist in forest land.

Some animals, such as the ibex, mouflon and goats, are confined to mountains; others (*e.g.*, beavers, otters, and water voles) only exist near rivers. Again, rivers and marshy land may be effectual barriers to the migration of the class of animals which thrive best in dry and hilly regions. Ice-floes often carry Arctic animals to distant continents and islands, and floating masses of earth and trees have been known to convey monkeys, tiger-cats, squirrels, pumas and many other quadrupeds many hundreds of miles from their native country. The main causes regulating the range of birds are the supply and nature of the food, soil, climate, and the prevalence of destroyers to the parent, the young, or the eggs. Forest country is necessary for the existence of some birds, open plains for others. It is generally known that many birds migrate from one country to another at certain seasons of the year; the cuckoo, swallow and swift visit us in the summer, the fieldfare, redwing and duck in the winter.* The probable cause of this migration is to search for food, the birds moving to the different districts as certain fruits become ripe. Reptiles are very dependent upon climate, and an effectual barrier to the dispersion of amphibia are deserts and oceans. Changes of temperature and of depth of water are the main barriers to the dispersal of fish, some existing best in cold water, some in warm, whilst others only live near the shore or in shallows.

Insects differ from birds and mammals inasmuch as they can exist for a much longer time without food. They are dispersed by means of floating drift wood, winds, and hurricanes. Many insects from the tropics are brought over to England in timber, and sometimes emerge after existing in the wood several years, even when the wood has been made up into articles of furniture. It has been shown in previous chapters that the continental plateau has not always had the same form as at present. The shape and height of the land, the depth and width of the seas must have been different in past ages from what they are now, and these alterations must have exerted a considerable influence upon the distribution of life. To take an example near home, the fact might be advanced that England was once connected with France, and this fact explains the great similarity that exists between the fauna and flora of the two countries.

The similarity of Europasian and North American fauna and flora may also be accounted for by the fact that the two regions were more closely united than now. There is also little doubt that Australia was isolated from the continental plateau by the gradual subsidence of the land which connected them.

To explain all the minute differences, however, necessitates the assumption of a succession of unions and separations, and it behoves us to own that although the investigations of naturalists in recent years have thrown very considerable light upon the matter there is much that still remains problematical.

GENERAL SUMMARY OF CHAPTER XVII.

Vertebrata is the name given to the group of animals having a backbone and an internal skeleton. It is subdivided thus:—

Division I.	Classes.	Orders.
Vertebrata	Fishes Amphibians Reptiles Birds Mammals	Marsupials. Edentata Pachyderms. Ruminants. Rodentia Carnivora. Quadrumana. Bimana.

Other divisions of the animal kingdom are:—

Division II.—Articulata or jointed animals.
Division III.—Mollusca or pulpy animals.
Division IV.—Radiata or rayed animals.

Plants are classified thus:—

Cryptogams.	Phanerogams.
Acotyledons.	Monocotyledons, Dicotyledons.

Fauna is the general name used for the various animals living in any particular country or district.

Flora is the term used to denote the trees and plants of a particular country or locality.

The Eight Vegetable Zones are :—

Name.	Characteristic Plants.
Equatorial	Palms, Bananas
Tropical	Tree-ferns, Figs
Sub-tropical	Myrtles, Laurels
Warm-temperate	Evergreen Trees
Cold-temperate	Deciduous Trees
Sub-arctic	Coniferæ
Arctic	Rhododendrons, Lichens
Polar	Alpine herbs

The Animals on the Earth were divided into six regions by Dr. Sclater in 1857, which are stated by Dr. A. R. Wallace as follows :—

The Palæarctic Region; including Europe, Temperate Asia, and North Africa to the Atlas mountains.

The Ethiopian Region; Africa south of the Atlas mountains, Madagascar, and the Mascarene islands with Southern Arabia.

The Indian Region; including India south of the Himalayas to South China and to Borneo and Java.

The Australian Region; including Celebes and Lombok eastward to Australia and the Pacific Islands.

The Nearctic Region; including Greenland and North America to Northern Mexico.

The Neotropical Region; including South America and Antilles, and Southern Mexico.

The Number of Peculiar Families in each of these regions is as follows:—

	Vertebrata		Mammalia		Birds	
	Families	Peculiar Families	Genera	Peculiar Genera	Genera	Peculiar Genera
Palæarctic ...	136	3	100	35	174	57
Ethiopian ...	174	22	140	90	294	179
Oriental ...	164	12	118	55	340	165
Australian ...	141	30	72	44	298	189
Neotropical ...	168	44	130	103	683	576
Nearctic ...	122	12	74	24	169	52

The Chief causes affecting Distribution of Animals on the earth's surface are:—

(1) Climate.
(2) Power of migration or transport.
(3) Geological changes in land and water surfaces.

The Chief causes affecting the Distribution of Plants are:—

(1) The mean temperature.
(2) The range of temperature.
(3) Distribution of temperature throughout the year, *i.e.*, lengths of summer and winter.

CHAPTER XVIII.

MANKIND.

MAN is a vertebrate animal and possesses similar characteristics to all other mammals. There is little structural difference between Man, the Gorilla, Chimpanzee, Ourang-Outang, Baboon and other quadrupeds; each has a jointed backbone, a spinal nerve-cord and a brain, and all of them nourish their young in the same manner. Truly the mental capacity of civilised man is much beyond that of any animal, but the structure of his brain differs less from that of the chimpanzee than the brain of the chimpanzee differs from the lemur of Madagascar, yet both of these belong to the monkey tribe. It seems very probable, therefore, that the higher as well as the lower animals have evolved from common ancestors, and therefore the different races of men are only varieties of a single stock; hence the most cultivated men must have descended from the same remote ancestors as the lowest savage, although there is more difference between the two than there is between the savage and a gorilla.

The similarity of the races of men may be demonstrated by many means, of which the evidence of language or philology is perhaps the best. Thus, the English language belongs to the same stock as that of the Hindoo, although the two people differ in external appearance. If the difference in language is considerable it is supposed that the separation of the races took place at a very remote period, and by studying the languages of various races it has been proved that often tribes separated geographically from each other to a considerable extent are descended from the same people.

The study of the whole question of the varieties and distribution of mankind on the surface of our globe is termed **Ethnology** and the simplest division is into three great classes or types called the Black, Yellow, and White. Each of these classes is sub-divided into groups or tribes possessing similar languages, customs and physiological characteristics.

The Black Type of mankind is characterised by dark brown or black skin, woolly or kinkled hair having a flat section, skull flattened at the sides and rather long, projecting jaws, low retreating forehead, similar to the lower animals, flat, broad nose, and thick protruding lips. The different branches of this type are as follows:—

Race.	Where found.
The Papuan.	New Guinea, Borneo, the Philippines and other islands in the Pacific.
The Hottentots.	Southern Africa (Cape Colony).
The Kaffirs.	Zululand, Zambesi, Mozambique and the Congo.
The Negro.	Soudan, southern part of the Sahara.

This is the least civilised type of mankind. None of the races have a written history, and their religion is fetishism, that is, they suppose inanimate objects such as trees, carved pieces of wood, streams, clouds, etc., to be gifted with the power to work good or evil. They have been enslaved from time immemorial, and although many Africans have become civilised and accepted a higher religion, the race as a whole seems to show little aptitude for such advancement.

The Yellow Type of mankind is characterised by skins which in the various sub-divisions vary in colour from yellow to yellowish brown, coarse and straight black hair circular in section, scanty beard, skull somewhat square-shaped, jaws less prominent, and forehead less retreating than in the black type, broad face. high cheek-bones, eyes almond-shaped, rather sunk and set slantingly towards the small, wide nose. This type may be sub-divided into the five following races :—

Race.	Where found.
Australian.	Main-land of Australia.
Malay.	Malaysia and Polynesia.
Mongolian.	Central and northern Asia, China, Japan, Burmah, Siam, Cochin-China, and the Arctic sea-board.
a. Lapps.	Scandinavia.
b. Finns.	Scandinavia and Central Russia.
c. Magyars.	Hungary.
d. Turks.	Asia Minor and Balkan Peninsula.
Esquimaux.	North American Arctic regions, and north-east extremity of Asia.
American or Red Indian.	Parts of North and South America.

The Australian aborigines, that is, the native inhabitants of Australia, are included in this type because their hair has the same appearance, although they represent the least highly organised man. Excepting this group, the mental development is higher than in the black type. The natives of Malaysia and Polynesia are daring, apt, and clever, and differ considerably from the stunted and miserable Australian aborigine.

The American Indian includes all the native races which peopled North and South America prior to the time of Columbus. In the former continent the race is fast dying out; in the latter it has been little interfered with; but its representatives, *e.g.*, the Fuegians, or the natives of Tierra del Fuego, are among the most degraded of mankind.

The White Type of humanity is distinguished by light-coloured skin varying from fair to tawny tinged with pink, an abundance of soft wavy hair, elliptical in section on the head and chin, large and elevated cranium, jaws and forehead almost in the same vertical line, narrow nose and small mouth. The sub-divisions of this type are as follows :—

Race.	Where found.
Dravidian.	Ceylon and Deccan.
Nubian.	Nubia, Kordofan and Dongola.
Caucasian or Mediterranean.	Formerly in South-west Asia, Northern Africa and the whole of Europe, but now over the whole globe.

The Caucasian race is divided by language into four different classes, viz. :—

(1) The Basques, occupying a region on the northern coast of Spain, and probably identical with.

(2) The Caucasians, dwelling about the Caucasian mountains.

(3) The Semitic or Syro-Arabic, including Hebrews, Berbers and Arabs and Hamites or people of Northern Africa with languages allied to Ancient Hebrew.

(4) The Aryan or Indo-European branch embraces Persians, Hindoos, Greeks, Latins, Celts, Slavonians, Germans, and many other groups, with languages allied to Sanscrit. This class includes most of the Caucasian race.

Other systems of classification have been adopted, Professor Huxley excluding the Australian aborigine from the second type and distinguishing four chief races, viz. :—(1) The Australian. (2) The Negro. (3) The Mongol. (4) The European or White Man; this also being their order of mental development. The classification may be tabulated thus:—

Race.	Typical Groups.
Australian.	Australian Aborigines. Coolies of Southern India.
Negro-like.	Negroes. Bushmen.
Mongolian.	Mongols. Malays. Polynesians. American Indians.
European.	Caucasians. Celts. Spaniards. Arabs.

A classification, which has much to recommend it, was made by Blumenbach in 1781. It recognises five races of mankind, viz.:—

(1) The Caucasian or White Race.
(2) The Mongolian or Yellow Race.
(3) The American or Red Race.
(4) The Ethiopian or Black Race.
(5) The Malay or Brown Race.

The considerations which render more elaborate classification necessary are too advanced for a work of this character. The general relation of the different arrangements to one another can easily be understood if the American and Malay-Polynesian sections be reckoned as sub-varieties of the Mongolian race.

The number of people on the earth has been estimated as 1,450,000,000, and nearly 83 per cent. of these belong to the Caucasian and Mongolian types.

The relative number of people in each group has been stated as follows:—

Caucasian	625,000,000.
Mongolian	575,000,000.
Negro	130,000,000.
Dravidian...	34,000,000.
Malay	30,000,000.
Kaffir	20,000,000.
American Indian ...	12,000,000.
Nubian	10,000,000.
Papuan	2,000,000.
Australian	100,000.
Hottentot	100,000.
Esquimaux	100,000.
Mixed races	11,700,000.

Although many hundreds of different languages and dialects are spoken by these races, yet seven languages serve 950,000,000 or nearly 66 per cent. of the human race. These are as follows:—

Chinese	400,000,000.
Hindustani	200,000,000.
English	100,000,000.
Russian	100,000,000.
German	60,000,000.
French	45,000,000.
Spanish	45,000,000.

Many conditions have effected the advance of some races, the stationary state and degradation of others. The natural surroundings and the form of government and religion aid considerably in shaping the character of a nation. It is a remarkable fact that the native inhabitants of the north temperate zone were always more civilised than those of the torrid and frigid zones, and a possible explanation is that in this zone a greater incentive to activity exists.

The struggle for existence, which is dependent upon geographical and physical conditions, is an important item.

Where there is a marked difference between summer and winter temperatures a certain amount of thought is necessary in order to store food for the season when no crops occur, and the exercise of this thought develops the higher faculties of the mind and is the means of lifting man from a state of savagery into one of civilisation. Other causes assist in such a development of mental capacity, and perhaps an extensive land area is the most favourable, inasmuch as it means the development of a greater number of tribes and a keener competition for mastery; for man, like the lower animals, has had so far to subscribe to the law of the survival of the fittest.

GENERAL SUMMARY OF CHAPTER XVIII.

The Types of Mankind have been arranged as follows:—

The Black Type.

Negroes.
The Papuan Negro.
Hottentots.
Kaffirs.

Total 152,100,000

The Yellow Type.

Mongols.
American Indians.
Esquimaux.
Malays.
Australian Aborigines.

Total 617,200,000

The White Type.

Dravidian.
Nubian.
Caucasians:
(*a*) Semites and Hamites.
(*b*) Aryans.

Total 669,000,000

The Characteristics of these Types are shown in the following table :—

The Black Type—Colour of skin, dark brown to black.
Hair, woolly and flat.
Shape of skull, long and narrow.
Profile, slanting from jaws.
Nose, flat and broad.
Religion, fetishism.

The Yellow Type—Colour of skin, yellow to olive.
Hair, straight and round.
Shape of skull, round.
Profile, slight slant.
Nose, small and wide.
Religion, polytheism.

The White Type—Colour of skin, fair to tawny.
Hair, wavy and elliptical.
Shape of skull, oval.
Profile, vertical.
Nose, narrow.
Religion, monotheism.

PUPIL TEACHERS' EXAMINATION PAPERS.

What is the influence which the moon has upon the earth? What relationship does it bear to the other planets, and what place does the earth occupy in the planetary system?

What are **latitude** and **longitude**? Say from what places they are reckoned, and, if you can, how they are calculated.

Explain, as to an upper class, the causes of the monsoons, and state what phenomena attend the changes of the monsoons.

Write what you know about the moon.

Compare the Atlantic and the Pacific Oceans.

Account for the various formations of

(*a*) Rivers.
(*b*) Mountains.

And give examples to illustrate your answers.

What do you understand by latitude and longitude? Show how degrees of longitude vary in length. Whereabouts is a ship whose latitude is 51½° N. and whose longitude is 1° E.

State what you know of the causes of

(*a*) Ocean currents.
(*b*) Winds.

How is commerce affected by (*a*) or (*b*) or both?

Say what you know of the causes of the tides. How is London as a port affected by tidal influence?

What do you know of the currents of the Indian Ocean?

Account for the dryness of the desert of Gobi, and name the other deserts and plains of Asia.

Give a short description of the Solar system.

Describe, as to a class, the changes the moon undergoes each month.

Explain the terms **latitude, longitude, planet** and **planetary system** as to a fourth standard class.

How do mountains contribute to the earth's fertility?

When it is 12 o'clock mid-day in London the time at New York is about 7 a.m. How can you explain this?

The mountain chains which enclose the Chinese Empire form the great watershed of Asia. Name the mountain chains and show the truth of the statement.

How are winds and ocean-currents influenced by the heat of the sun?

What is meant by spring-tides, neap-tides, and a tidal 'bore.'

How are the Trade Winds caused? Name the chief ocean currents, and describe briefly the course of one of them.

How is the tidal wave caused? Show the positions of the sun, moon and earth at spring and neap-tides, and compare the sizes of the three bodies.

Explain, with diagrams, why the days are (1) longer and (2) warmer in Summer than they are in Winter, and (3) why the heat of Summer is rather greater in the Southern Hemisphere than in the Northern.

Enumerate the various ways in which rivers originate, with illustrative examples.

What is meant by a **degree of longitude?** What is its length in miles in Latitude 0° and Latitude 90°, respectively?

Show the effect of (*a*) the earth's rotation and (*b*) the heat of the tropics upon winds and ocean currents.

Explain the difference between a **group** and a **chain** of mountains, and illustrate your answer by examples.

What is the difference of time between London and a place whose longitude is 25° E.? Account for this difference and give the latitude and longitude of London and three other places.

What are the causes of winds? What is meant respectively by Variable winds, Periodical winds, Trade winds? How may Trade winds be accounted for?

Name the planets and give any particulars you can respecting their sizes, their distances from the sun, and the periods of their revolution.

Explain, as to a class of children, the meaning of these terms:—**A tidal river, spring-tide, high water, neap-tide.**

Explain the terms 'watershed' and 'river-basin,' and illustrate your explanation by examples from the North of England or from British North America.

What is meant by **constant** winds, **periodic** winds and **variable** winds? Give examples of each as far as you can.

Name some of the principal animals, trees and fruits which are not found in England, but are to be met with either in (*a*) India or (*b*) Australia.

When it is 12 o'clock in London, what is the time in two places of which the one is situated 45° E. longitude and the other in 75° 36′ W. longitude? Explain as to a class of children the reason of this difference.

What is meant by a Trade Wind and by the Gulf Stream? Explain the reasons of **one** of them as to a class in the Seventh Standard.

Draw either a map of the West Indies, or a diagram illustrating a lunar eclipse and showing the reason of it.

Gibraltar is situated in 36° 8′ N. latitude and 5° 20′ W. longitude. Find (*a*) its distance in miles from the equator, (*b*) the time there when it is noon at Greenwich.

Name some of the principal ocean currents and constant winds, and explain their causes in the cases of the Gulf Stream and the Monsoons.

What are exterior and interior planets? Give their names, their order of magnitude and mean distance from the sun.

Explain the terms meridian of longitude, great circle, Arctic circle; and explain how in going round the world from East to West a day is apparently lost What is the difference in time between a place in 45° W. longitude and another in 15° E. longitude?

Explain the terms monsoon, great polar current, and explain why, in summer, a sea-breeze springs up at the sea-side in the morning and dies away in the afternoon.

In what parts of the world are the Sikhs, Mongols, Hottentots, Malays, Arabs and Parsees chiefly to be found?

Draw diagrams showing the moon in her third quarter, the position of Venus as an evening star, the position of the sun and moon for a neap-tide and for an eclipse of the moon.

The mountain ranges of Europe run east and west as a rule. Name some ranges which follow this rule, and some which do not follow it, and give a particular account of one of those named.

What is meant by 'latitude'? What by 'longitude'?

When it is noon at Greenwich it is half-past two in the afternoon at Moscow. Can you explain this?

Mention a few of the circumstances upon which the climate of a country depends, and illustrate your answer by reference to some of the British possessions.

Write what you know about the causes of ocean currents. Trace the course of the Gulf Stream.

Explain the meaning of the word 'Planet,' write out a list of the planets in the order of their distances from the Sun, and explain the term 'Transit of Venus.'

Tell what is meant by the 'phases of the moon' and explain the cause of them. What are the relative positions of the Sun, Moon and Earth at New Moon and Full Moon?

Explain the terms trade winds, monsoons, cyclone, typhoon, tidal-wave. Of what use are the trade winds in a voyage from England to Australia?

QUEEN'S SCHOLARSHIP EXAMINATION QUESTIONS.

How could you explain to a child the reasons for concluding that the earth moves round the sun and not the sun round the earth?

If it is five o'clock in the afternoon at some place when it is twelve o'clock midnight at Greenwich, what is the difference of longitude, and is it east or west? Give your answer, with reasons for it.

Explain **latitude** and **longitude** of a place on the earth. How would you instruct a child to find on the globe a place of which the latitude and longitude are given?

What is meant by the ebb and flow of the tide?

What are the tropics, the equator, the arctic circle, the poles?

Name the great oceans on the earth's surface and give their relative positions. Which of them has the most islands? State what you know of the depth of the ocean and its saltness.

Give in miles the length of the sun's diameter, of the equator, of the sun's distance from the earth, and of England.

What are parallels of latitude and longitude? Give the latitude of some of the chief cities of the world.

Define cape, zone, watershed, peninsula, volcano.

Define the terms estuary, strait, archipelago, valley. Illustrate your definition of the first from America, of the second from Asia, of the third from Europe, of the fourth from Great Britain.

Give accurately the shape of the earth, its equatorial and polar diameters, the proportion of land and water on its surface, the position of the polar and tropical circles, the latitudes of London and Edinburgh.

State clearly how deltas and glaciers are formed. Draw your illustrations from the continents of Europe and Africa.

How could a globe be used to explain the varying length of day and night according to the seasons of the year, the different times of day at places in the same latitude, and the method employed in geography for determining the position of a place on a map? What decimal part of an inch would represent the height of a mountain eight thousand feet high on a globe sixteen inches in diameter?

Define the geographical terms in the following, and give examples of each from the continent described. 'The surface of Europe is diversified by mountains, plains, plateaus, and valleys; it lies almost wholly in the North Temperate Zone; its coast is deeply penetrated by inland seas and numerous gulfs.'

Write a short explanatory account of five of the following.—The variable length of twilight at different places having the same longitude; the difference of forty-seven minutes between the mean time of Paris and Rome; the trade winds; the torrid zone; the cause of the moon's phases; the north-east passage; glaciers; the processes employed for travelling through mountains.

Give the full meaning of the terms tropic, meridian, longitude, solstice, coral-reefs, with appropriate diagrams in each case.

Explain the terms cardinal points, horizon, meridian, plateau; give the difference in time, and the distance between, two places situated on the equator in long. 40° E. and long. 40° W. respectively, and state the latitudes of London, Edinburgh, Dublin, and Liverpool.

Explain and illustrate by a diagram (*a*) The phases of the moon, or (*b*) the succession of the four seasons, or (*c*) the variation in the length of day and night.

What is meant by the terms as applied to rivers—watershed, tributary, affluent, left bank, bed, fall, volume, and basin?

What is meant by 'climate'? What are the chief causes affecting it? Describe the influence upon it of each.

Explain the following terms meridian of Greenwich, equatorial diameter, ecliptic, solstice, estuary, confluence and plateau.

Distinguish physical and political geography and explain the terms degree of latitude, west longitude, tropic of cancer, watershed, delta, and Gulf Stream. What changes have been recently determined upon by astronomers representing the leading nations of the world in the estimation of the longitude of a place, and of the time of day?

Explain briefly the terms inferior planet, phases of the moon, perigee, morning star, neap tides, and draw diagrams illustrating the second and last.

Explain, as to an upper class of children, the difference in time between London and Cairo; or between London and New York; and the reasons for the difference.

Explain, as to one of the upper standards, why it is warmer in summer than in winter.

State briefly what is meant by constant winds and ocean currents. The Gulf Stream is said to influence the climate of these islands. How would you explain this?

What is the 'Solar System'? Draw a diagram to illustrate your answer.

Give notes of a lesson on an eclipse of the moon.

State the causes of the difference between (1) Spring Tides and Neap Tides; (2) and between the tides (*a*) in the Pacific Ocean, (*b*) in the Atlantic Ocean, (*c*) in the seas around the British Isles, and (*d*) in the Baltic Sea.

CERTIFICATE EXAMINATION QUESTIONS.

Give a sketch of a lesson to an upper class of scholars on the forms and uses of vapour.

Name the principal animals to be found in the torrid, the temperate, and the frigid zones respectively, and say what circumstances account for their geographical distribution.

Who are the Parsees, the Hindoos, the Maories, the North American Indians, and the Zulus respectively?

Describe the principal mountain chain of Australia and its vegetable and animal productions.

Explain the terms in *italics* in the following passage. In the year 1886 there will be a *total eclipse* of the sun on August 29th, invisible at Greenwich. Begins at 10h. 19m. a.m. (Greenwich Mean Time) in *long.* 66° 24′ W., and *lat.* 11° 55′ N. The *central eclipse* begins at 11h. 14m. a.m. in long. 79° 46′ W. and lat. 9° 48′ N. What part of the British Empire would be a favourable position for observing this eclipse? What is the object of sending out an 'eclipse expedition'?

Prepare the outline of a lesson to the Seventh Standard on tides.

How may it be determined by measurement that the earth is not spherical? Why is the solar day an unfit measure of time? What is the mean solar day?

The capacity of the air for vapour is regulated by its temperature. Explain this. How can the height of the atmosphere be approximately determined? What are the main causes of variations in atmospheric pressure at a given place?

Explain the causes of land and sea breezes. Describe briefly the cause and course of the equatorial current.

Give some reasons (with brief explanations) why isothermal lines do not coincide with parallels of latitude. Does it follow that two places which have the same average yearly temperature have also the same climate?

How far are the expressions 'temperate flora,' 'tropical fauna' correct: *i.e.*, does identity of latitude with similarity of climate imply agreement in the character of the flora and fauna? Give examples.

Give some account of the climate of Australia, and of the principal animals to be found there. Remark on any difference you have observed in the description of the native animals of Australia and the animals of the Asiatic continent.

What are the principal motions of the earth? Explain how it is that varying seasons and days and nights of unequal duration are caused by the plane of the equator being inclined to the plane of the ecliptic.

How far does the atmosphere extend, and of what gases is it composed? Explain the term rarefaction. Why are we not crushed by the weight of the atmosphere? Explain the following lines from Shelley's 'Cloud.'

'I am the daughter of earth and water,
And the nursling of the sky;
I pass through the pores of the ocean and shores,
I change, but I cannot die.'

How do you account for the inequality of the heights to which the tides rise in different places? Explain how hot, cold, and under or counter-currents are caused. What currents would you meet with off the coast of Japan, the North Cape, and the South Coast of Africa?

The difference between the summer heat and winter cold of Moscow is 82°, whilst that of London is 57°. How do you account for this? Mention, with instances, the chief causes which determine the climate of a country.

Who are the Bushmen, the Red Indian, the Cingalese, the French Canadians, and the Sikhs respectively?

Explain why in the belt between the tropics the sun appears vertical in the sky twice in a year. Why does not an accurate clock always indicate twelve when the sun is on the meridian? Why are three of the leap years common years in each cycle of 400 years?

How is rain formed? Why is the rainfall on the west of Great Britain greater than on the east? Explain why the country on the east of the Western Ghats receives comparatively little rain.

Explain the terms constant winds, periodic winds, local winds, with examples. What are spring-tides? At the port of Batsha the tidal-wave comes in by two distinct channels, such that the time of arrival of the one is six hours later than of the other. How will the tide there be affected?

How is climate affected (1) by distance from the equator, (2) by local influences? Why are the climates in the southern hemisphere distributed with much regularity according to latitude?

Give some account of the plants and animals found in Australia.

What difference can you observe—

(*a*) Between the position of the sun when it is rising in December and when it is rising in June?

(*b*) Between its position at noon in December and its position at noon in June?

(*c*) In the ebb and flow of the tide of new moon, half moon and full moon?

Give answers to (*a*), (*b*) and (*c*), and in one case give an explanation of the cause of the difference.

APPENDIX.

ORDER OF STRATIFICATION OF ROCKS.

◆

AN examination of the rocks which constitute the crust of the earth shows that they may be divided into two great classes. Those that lie in more or less parallel layers, such as sandstone, clay, limestone, shale, etc., are termed STRATIFIED, SEDIMENTARY, or AQUEOUS ROCKS, the last two names signifying that they were formed by the deposit of matter once suspended in water. Those that are not so arranged and show evidence of having been at one time in a melted state—*e.g.*, basalt, lavas and granite—are called UNSTRATIFIED or IGNEOUS ROCKS.

There is no doubt that the first class of rocks originally existed as loose deposits forming the beds of rivers, lakes and seas. The mud, sand and gravel accumulated in layers in just the same manner as may be seen going on at the present time. And as the layers were piled up one upon another, those at the bottom were subjected to a pressure so enormous that they were hardened into stone, or, in some cases, the loose particles became cemented together by the slow deposition round them of other mineral substance; or both these causes may combine to consolidate the material and produce compact stone. And obviously with regard to the comparative ages of the strata, those at the bottom must be the oldest, and the others were successively deposited upon them until the newest rocks are reached at the top.

Objects are frequently found in stratified rocks, which differ entirely from the deposits in which they occur. Thus a piece of shale may have upon it the remains of a fern leaf, and a close examination makes the fact apparent that the leaf must once have formed part of a living plant; or perhaps shells, bones, or trees may be found. These objects are called FOSSILS. True fossils are those in which all the organic matter has decayed away and been replaced by mineral substances, so that an exact model of the original body is preserved. But the term is also extended to apply to markings on sandstone resembling the ripple-marks often observed on the soft sand of a shelving beach, to footprints, to the pittings produced by raindrops when the sandstone in which they occur was soft and moist, etc., and often, instead of the original shell, bone, or other object being preserved, not a particle remains, but only "casts" or hollow spaces showing the markings of the body previously enclosed in them.

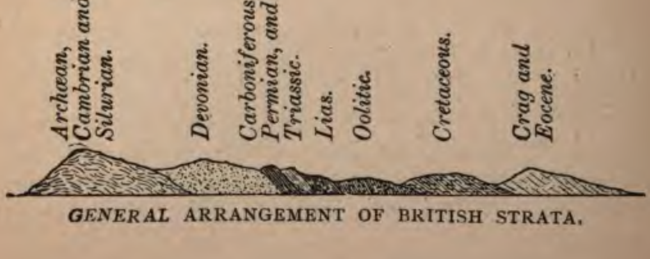
Fossils show the conditions under which the deposit of material in which they occur took place, and enable the age of a stratum to be estimated. In general, the older a rock the greater is the difference between the fossils found in it, and the plants and animals existing at the present time. Geologists divide the stratified rocks into periods based upon the kinds of life which lived during each of them respectively. It is found that fossils of vertebrate animals afford the most reliable evidence of climatic and other geological changes, and therefore best serve to mark geological time. The oldest rocks, in which life is unknown, are known by the name of *Archean* or *Pre-Cambrian*. Then follow the *Primary* or *Palæozoic* rocks in which a few fossil plants are found, and low forms of fishes, amphibians and reptiles. In the succeeding *Secondary* or *Mesozoic* rocks plants are very abundant, and the first mammals are found, also enormous reptiles. During the *Tertiary* or *Cainozoic* period the higher organisms, both of plants and animals, were developed and became more like those of the present day.

Each of these four great divisions represents enormous periods of time and great thicknesses of strata, and are divided into smaller *systems* or *formations* as shown in the following table.—

Tertiary or Cainozoic	Post-pliocene. Pliocene. Miocene. Oligocene. Eocene.
Secondary or Mesozoic	Cretaceous. Neocomian Jurassic. Triassic.
Newer Palæozoic	Permian. Carboniferous. Devonian.
Older Palæozoic	Upper Silurian. Lower Silurian. Cambrian.
Archean.	

It is hardly necessary to say that the formations shown above do not lie regularly upon one another from the Archean upwards like the coats of an onion. If this were so it would be impossible for us to know anything about the older rocks. In consequence of the movements which are continually going on in the earth's crust, the strata, which were deposited in more or less horizontal layers, have been tilted up at various angles and sometimes occur vertically. These upheavals have brought the older rocks to the surface and enabled them to be investigated. But although the succession indicated in the table may be considerably interrupted by some intermediate beds having been worn away or accidentally disturbed, the order of the strata always remains unaltered, that is to say, Cretaceous rocks are always above Carboniferous, and Devonian, or Old Red Sandstone, below them, except in a few places where great disturbances have forcibly caused an inversion of strata.

This arrangement will be at once understood from an examination of a geological map of England, that is, a map showing the different systems of rocks which appear at the surface. Roughly speaking, in travelling across England and Wales from Harwich to St. David's Head, we first meet with the clays, sands and gravels belonging to the Tertiary system; these rest upon the Cretaceous rocks exemplified by the chalk downs of South-east England, whilst the Cretaceous in turn lie over the Oolitic limestones, shales and sandstones of the Jurassic system, which occur in the Midland counties. Dipping under the Oolites is found the blue Lias which stretches from Lyme Regis to Whitby in an irregular line, and then the red sandstones and marls of the Triassic system. The magnesium limestones of the Permian system pass under these and over the coal measures, millstone grits, and carboniferous limestones, which characterise the carboniferous period. The next formation consists mainly of a reddish coloured sandstone known as Devonian or Old Red Sandstone, and illustrated by rocks in Hereford and South Wales. The Upper and Lower Silurian and the Cambrian gritstones and shales pass under these in succession, and finally rocks of the Archean period are reached. This arrangement of systems of rocks one upon another is illustrated diagrammatically by the accompanying section.


Archæan, Cambrian and Silurian.
Devonian.
Carboniferous, Permian, and Triassic.
Lias.
Oolitic.
Cretaceous.
Crag and Eocene.

GENERAL ARRANGEMENT OF BRITISH STRATA.

RAINLESS REGIONS AND THE CAUSES OF THEIR ARIDITY.

Besides the districts noted on p. 145 as having very little rainfall, there are certain almost Rainless Regions whose aridity depends not only upon the general conditions we have laid down, but on other causes. The Desert of Sahara is a well-known tract of this character. In it the rains are generally of short duration and of small geographical extent. The cause of the small rainfall of the Sahara does not appear to be precisely the same in summer as in winter, and different explanations have been put forward to account for this. The late Prof. Loomis, in his masterly discussion of the rainfall of different countries of the globe, published at New Haven in 1889, considers the two cases separately, and we cannot do better than quote his opinion:—"In winter the northern margin of the equatorial rain-belt [see p. 159] retreats almost to the equator, so that with slight exceptions the whole of Africa, from the parallel of 30 deg. down almost to the equator, is well-nigh rainless. Throughout this whole region the distribution of atmospheric pressure, temperature and humidity, are such as to cause a prevalence of northerly winds. From lat. 30 deg. to the equator the average pressure diminishes somewhat over a quarter of an inch, which gives an average gradient of about 0·01 inch for each degree of latitude. The temperature increases by more than 30 deg., and the humidity of the air alse increases. These causes are sufficient to determine a prevalent wind from the north, and all the observations we have from this region fully confirm this conclusion. These northerly winds in their progress towards the equator are continually advancing into a warmer region, that is, they are becoming drier, and this is a condition unfavourable to rainfall. . . . . . . In summer the distribution of temperature and pressure over Africa are very different from what they are in winter. In summer the highest temperature is found near the parallel of 20 deg. N., and here the mean temperature is about 100 deg. Fahrenheit, or 20 deg. greater than it is on the equator. The result of this intense heat is that the air is expanded, it swells up and flows off to other parts of the globe, leaving a diminished pressure over the region of greatest heat. Thus, in summer over Northern Africa, there is a permanent area of moderately low pressure, whose centre is near lat. 17 deg. N., and here the mean pressure is about a quarter of an inch less than it is at the equator. This distribution of temperature and pressure determines the direction of the prevalent winds. In Northern Africa, down to near the parallel of 17 deg., northerly winds prevail, and they generally have an inclination to the north-east. Between the parallel of 17 deg. and the equator, southerly winds generally prevail. The rainfall is intimately connected with the direction of the prevalent wind. In Northern Africa, where northerly winds prevail, the atmosphere advances from a cooler to a warmer region, which is a condition unfavourable to rainfall. But this case is counteracted by a much more powerful influence. The great equatorial rain-belt which is the result, not of local causes, but of causes which depend upon the general circulation of the atmosphere for the entire globe, advances in summer into the northern hemisphere, and the resulting rains sometimes extend northward to lat. 17 deg. Thus in summer the rains of Africa extend from the equator to near the parallel of 17 deg. N.; but north of this line the entire continent is well-nigh rainless. The result for the entire year is that there is an extensive region where the mean annual rainfall is less than 10 inches. The boundaries of this region are somewhat irregular, but the southern boundary is near the parallel of 17 deg., and the northern boundary is somewhat north of the parallel of 30 deg."

The aridity of the ARABIAN DESERT may be similarly explained. In winter northerly winds prevail, and the general result is an almost entire absence of rain. In summer southerly winds prevail to about lat. 20 deg. N., but north of this northerly winds prevail. The conditions are therefore like those of the Sahara, both in this respect and in the fact that the country is situate upon a plateau from 3,000 to 5,000 feet above sea level.

Similar conditions prevail throughout the region of small rainfall in PERSIA and BELUCHISTAN, for this region has an elevation of from 4,000 to 6,000 feet.

THIBET owes its desert character to its position on the leeward side of the Himalayas, and its extreme elevation.

The Great Sandy DESERT OF GOBI is the result of three causes as far as rainfall is concerned, viz.—(1) considerable elevation; (2) its prevalent winds blow from a desert region; (3) the existence of a range of mountains in the south-east to take out the moisture of winds blowing from the Pacific Ocean.

The small rainfall in the vicinity of the CASPIAN and ARAL SEAS is due to some extent to position in the interior of a large continent. Northerly winds also prevail in the latter region at all seasons of the year, and these help to render it more arid than other parts of European Russia.

A region in the extreme north of Asia, and another in the northern part of North America, probably owe their small rainfall to remoteness from the ocean, measured in the direction of prevalent winds, and to their high latitude.

There is an area in Northern CALIFORNIA and ARIZONA in which hardly any rain falls. This is because a prevalent wind blows from the north, and as it blows from a colder to a warmer region, its capacity for holding moisture is increased—a condition unfavourable to rainfall.

In summer southerly winds prevail in the region of the

GREAT SALT LAKE, and as they tend towards an excessively dry region, little rainfall occurs.

The principal desert in the southern hemisphere is in AUSTRALIA. During the colder months of the year the winds blow from the interior of this continent, and this is a condition unfavourable to rainfall. During the warmer months the interior of Australia is extremely hot, hence, although the prevalent winds are then towards the interior, their capacity for moisture is increased, and therefore very little rain falls.

The small rainfall of the KALAHARI DESERT in South Africa appear to be the result of conditions similar to those of Australia, and therefore admits of a similar explanation.

It may therefore be said that, in general, during summer, the prevalent winds blow towards desert regions, and in winter the winds flow out of them. And as the majority of these regions are also surrounded more or less by high hills, a low rainfall is occasioned.

C. L. WRIGHT, PRINTER, GLASGOW.

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